SAHNI'S MINI SERIES

Physics Formulae

SAHNI'S

PHYSICS FORMULAE

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PREFACE

Although many treatises are available in the market, but few serve the purpose of those students who want to go in for a quick revision in the face of time constraints. This book certainly steps in at that moment and serves that purpose.

The book presents the subject in a simple and brief way to be digested by the students.

At the same time it provides a large number of terms and definitions. In short it is a ready recknor.

The book will not only help those appearing in their school examinations but also prepare them for the various competitive tests in this age of competition.

The book has been based on the syllabus of the U.P. Board, CBSE and NCERT

I have no doubt that the students would be immensely benefitted by the book.

I would like to invite constructive suggestions from readers so that necessary additions could be incorporated in future editions.

AUTHOR

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HEAT

Heat: It is an agent which produces the sensation of warmth. When an object is heated, its molecules begin to move faster. Heat always flows from a hotter body to a colder body. Heat is measured in calorie or kilocalorie. The SI unit of heat is joule (J).

Heating and Cooling of Substances: On cooling gases become liquid. When liquids are heated, they change to gases. When solids are heated, they change to liquids. Liquids solidify on cooling.

Calorie: It is the amount of heat required to raise the temperature of 1 gm of water through 1° C.

Kilocalorie: It is the amount of heat required to raise the temperature of 1 kg of

water through 1° C.

1 kcal = 1000 calorie.

Thermal Equilibrium: When two bodies come in contact in such a way, that no transfer of heat takes place from one body to another, then the bodies are said in thermal equilibrium.

Temperature: Temperature of a substance is the degree of its hotness or coldness. Three temperature scales are commonly used for the measurement of temperature. These are °C or °F or K.

(i) ***Celsius Scale:*** This scale was given by Celsius. On celsius scale, the temperature of melting ice, that is melting point of ice is given the value 0°(zero degree) and temperature of steam is given by 100°.

This scale has been divided into 100 equal parts or degrees. Since there are 100 divisions or degrees on the celsius scale, it is also called centigrade scale (centi = 100 and grade = division). Cel-

sius scale is used particularly in scientific work.

(ii) ***Fahrenheit scale:*** This scale was given by Fahrenheit. On Fahrenheit scale, ice point is given the value of 32° and steam point is given a value of 212°, so that there are 212 - 32 = 180 degree between the two fixed points. The Fahrenheit scale is generally used for household thermometers.

(iii) ***Kelvin scale:*** This scale was given by Kelvin. On this scale of temperature, ice point has a value of 273 K and steam point has a value of 373 k and there are 373 – 273 = 100 divisions between two fixed points. This is also known as Absolute scale of temperature.

Conversion of Celcius (°C) to Fahrenheit (°F) to Kelvin (K) Scale:

$$\frac{C}{100} = \frac{F-32}{180} = \frac{K-273}{100}$$

Also $K = C + 273$

Specific heat: It is defined as the amount of heat in calories required to raise the temperature of a unit mass of a substance by 1°C(or 1°K). The SI unit of specific heat is joules per kilogramme per kelvin i.e. J $Kg^{-1}K^{-1}$. The specific heat of water is 4200 J Kg^{-1} K^{-1}. The specific heat of water is maximum.

By stating that the specific heat of copper is 0.093 Cal/G ° C, means that 0.093 calorie of heat is required to raise the temperature of 1 gm of copper by 1 degree centigrade.

Molar specific heat at constant volume (**C_v**) It is the amount of heat required to raise the temperature of one mole of gas through 1 k, keeping its volume constant.

S.I.unit - J $mole^{-1}k^{-1}$

Specific heat at constant pressure (**C_p**) It is the amount of heat required to raise the temperature of one mole of gas through 1°C or 1 k, keeping its pressure constant.

S.I.units - J $mole^{-1} k^{-1}$

C_p is always greater than C_v

Relation between c_p and c_v

$$C_p - C_v = \frac{R}{J}$$

where R = universal gas constant measured in Joules.

C_p and C_v are measured in calories.

Thermal Capacity: Thermal Capacity is the amount of heat required to raise the temperature of whole body through 1° C.

Thermal capacity = mass of the body × sp. heat.

The SI unit of thermal capacity is joules per Kelvin (J/K). The common unit of thermal capacity is calories per degree C which is written as Cal/ ° or Cal C^1.

Types of Expansion: Solids expand on heating. The different types of expansions in solids can be classified as (i) linear (ii) superfluous and (iii) volume or cubical.

Linear expansion: Linear expansion means lengthwise expansion. It has been experimentally found that the increase in length of a metal rod, on heating is directly proportional to

(i) original length (ii) rise in temperature

Coefficient of linear expansion: It is the increase in length per unit length of solid when its temperature is raised by 1° C.

$$\text{Unit of (A)} = \frac{1}{°C} \text{ or } /°C \text{ or } °C^{-1}$$

Co-efficient of superficial expansion: It is the increase in area per unit area of a solid when its temperature is raised by 1° C. It is denoted by β. Mathematically $\beta = 2\alpha$.

$$\frac{\text{increase area}}{\text{original area} \times \text{rise of temperature}}$$

Superficial Expansion of Solid: The area wise expansion of metal sheet on heating is known as superficial expansion. It has been found that increase in area of a solid is directly proportional to the—

(i) Original Area (ii) Rise in Tempera-

ture

Relation between coefficient of (i) linear (ii) superficial (iii) cubical expansions.

(i) $\beta = 2\alpha$

(ii) $\gamma = 3\alpha$

Apparent expansion: Is the expansion of a liquid in which the expansion of its container has not been taken into account is known as apparent expansion.

Real expansion: Is the expansion of a liquid in which the expansion of its container has also been taken in account is known as its real expansion (or absolute expansion).

Coefficient of apparent expansion of a liquid: It is the increase in its volume per unit volume which appears to have taken place when it is heated through 1°C in a expandable vessel.

Coefficient of Cubical expansion: It is the increase in volume per unit volume of a solid when its temperature is raised by 1°C. It is denoted by γ. Mathematically

$\gamma = 3\alpha$.

or $$\gamma = \frac{V_1 - V_0}{V_0 (T_2 - T_1)}$$

where V_0 = initial volume of the body

V_1 = final volume of the body.

T_1 = initial temperature of the body

T_2 = higher (final) temperature of the body

Coefficiant of apparent expansion (γa)

$$= \frac{\text{apparent increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

Coefficient of real expansion of a liquid: The coefficient of real expansion of a liquid is the increase in its volume per unit volume which actually takes place when it is heated through 1°C.

Volume coefficient of expansion of a gas: The volume coefficient of expansion of a gas is the increase in volume of 1 cm^3 of the gas initially at 0°C when its temperature is raised by 1°C at constant-pressure.

Volume coefficient of gas

$$= \frac{\text{increase in volume}}{\text{original volume at } 0°C \times \text{rise in temp.}}$$

Fusion: Is the process in which a solid changes into a liquid on heating is called fusion or melting. When ice changes into water, it is called fusion of ice (melting of ice).

Vaporization: Is the process in which a liquid changes into a vapour (or gas) on heating is called vaporization. When water changes into vapour (steam) it is known as the vaporization of water.

Latent heat: The latent heat of a substance is the amount of heat absorbed by a unit mass of the substance to change its state without change of temp.

The latent heat of fusion of ice is 80 calories per gram mean that 80 calories of heat are required to change 1 gram of ice at its melting point of 0°C into a water at the same temperature (of °C).

Latent Heat of Vaporisation: It is the

quantity of heat required to change one kg of liquid to gas without change of temperature. Latent heat of Vaporisation of steam is the heat required to convert one kg of water to steam at 100°C. Latent heat of vaporisation of steam is 540 kcal/kg or 2.27×10^6 J/kg.

Calorimetry: The subject that deals with measurement of heat.

Principle of Calorimetry: When a hot body is mixed with cold body, then heat lost by the hot body is equal to heat gained by the cold body. or

Heat gained = Heat lost

Apparent expansion: The expansion of a liquid that includes the expansion of the solid container is denoted as apparent expansion.

Real expansion (absolute expansion): is the actual expansion of a liquid. This expansion does not include the expansion of the container.

Coefficient of apparent expansion of a

liquid:

$$\frac{\text{apparent increase in volume}}{\text{original volume} \times \text{rise in temperature}}$$

Coefficient of real expansion of volume: Is the actual increase in volume per unit volume per degree rise in temperature. It is denoted by γ_r

Volume coefficient of expansion of a gas: is defined as the increase in volume per unit volume at 0°C, when its temperature is raised by 1°C. Volume coefficient of a gas

$$= \frac{\text{increase in volume}}{\text{original volume at } 0^\circ C \times \text{rise in temp.}}$$

Relative humidity: is defined as the ratio between the amount of water actually present in a given volume of air to the amount of water it can hold

$$R.H. = \frac{m_1}{m_2} \times 100$$

where m_1 = mass of water present in the

given volume of air, and

m_2 = mass of water the given volume of air can hold.

One feels comfortable when temperature is 22- 25°C and R. H. about 50%.

Heat: The physical quantity which is exchanged between a hot and cold body during the time they are in contact and their temperature is changing is called *heat.*

Effects of heat: Materials expand on heating. Due to expansion of materials.

(i) a small gap is left between the rails.

(ii) sag is left in telephone and electric wires as they contract in winter.

(iii) a glass tumbler often cracks when boiling water is poured into it.

(iv) pipes are given loops at regular intervals.

(v) In the design of bridges, steel girders are placed on rollers.

Thermometric scale: This scale is used

for measuring temperature or degree of hotness of a body is known as thermometric scale or thermometer. Two fixed temperatures are required for setting the temperature range of any thermometer.

These two fixed temperatures are called the fixed points of the temperature scale.

(i) The melting point of pure ice under standard atmospheric pressure is taken as the lower fixed point of a temperature scale. It is also known as ice point.

(ii) The boiling point of pure water under standard atmospheric conditions is taken as the upper fixed point. It is also known as steam point.

Two commonly used scales are Celcius scale and Fahrenheit scale.

Celcius scale of temperature: This scale was prepared Celcius. The lower fixed point (melting point) of ice on this scale is 0°C, and upper fixed point (boiling point of water) on this scale is 100°C. The

whole scale is divided into 100 parts.

Fahrenheit scale of temperature: This scale was suggested by Fahrenheit. The lower fixed point on this scale is 32°F and upper fixed point is 212°F. Thus the number of degrees between the two fixed points on this scale = 212 - 32 = 180.

[In India Celcius scale is preferred over Fahrenheit scale. This is also the standard scale used in India.]

The following equations are used for converting Calcius temperature to Fahrenheit temperature and vice versa.

$$°C = \frac{5}{9}(°F - 32) \quad °F = 1.8(°C) + 32$$

Normally the temperature of a healthy person is 98.6° F or 37°C.

Phenomenon of Thermal Equilibrium: Imagine two containers (*i*) one of boiling milk and other (*ii*) of ice lying in a room. When both of these containers are kept in room, it is observed that the temperature of milk starts falling and ice begins to melt.

When they are but left for more time, it is observed that milk has cooled considerably whole of ice has changed into water. When this water is left for some time, the temperature of water starts rising.

Finally both the containers indicate the same temperature. It is also the temperature of the room in which these containers are lying. When the temperature of the body and its surroundings is the same, *the body is said to be in thermal equilibrium.*

This experiment shows that (*i*) heat flows from hotter body to colder body (*ii*) hotter body loses heat whereas colder body gains heat.

Method of Calculating specific heat: Specific heat of a substance is the amount of heat required to raise the *temperature of a unit mass of a substance* through one degree Kelvin (Celcius).

When a substance is heated, its temperature rises. When a hot body is

cooled, it loses heat and its temperature starts falling. The heat absorbed or given out by a substance is directly proportional to-

$$Q = m \times C \times T$$

where m = mass of the body (or substance)

C = specific heat of the body (or substance) *depends on the* nature of material of the body

T = change in temperature of the body (or substance)

Heat absorbed (or given out) = mass × specific heat × change in temperature

Specific heats of some substance at 20°C are given here

S. No.	*Substance*	*Sp. heat at 20°C (J/kg°C)*
1.	Water.	4.18×10^3
2.	Mercury	0.13×10^3

3.	Marble	0.90×10^3
4.	Glass	0.50×10^3
5.	Iron	0.48×10^3
6.	Copper	0.13×10^3

Thermal expansion: When a substance is heated, the energy of its molecules increases. In a solid, the molecules lie in a regular geometrical pattern in all the three dimensions.

Heating of a substance increases the lattice distance of a substance. It results in expansion of solids. It is a reversible process, and substance contracts on cooling. Expansion also takes place in liquids and gases.

Latent heat of Fusion: This heat of fusion of ice is the amount of heat required to convert 1 kilogram of ice into water at 0°C.

Similarly latent heat of fusion of solid is the amount of heat required to convert

one kg of solid into liquid at its melting point.

Latent heat of fusion of some substances

Substances	Latent Heat of fusion	
	Kcal/kg	J/kg
Ice	80	3.34×10^5
Copper	43	1.80×10^5
Lead	06	0.25×10^5
Silver	22	0.92×10^5
Zinc	27	1.13×10^5
Aluminium	76.8	3.21×10^5

Latent heat of Vaporisation: This latent heat of vaporisation of water is the amount of heat required to convert 1 kg of water into steam at its boiling point.

The latent heat of vaporisation of a substance is the amount of heat required to

convert 1 kg of liquid into vapours at its boiling point.

Latent heat of vaporisation of some substance

Substances	*Latent heat of Fusion*	
	kcal/kg	*J/kg*
Water	540	22.5×10^5
Mercury	68	2.8×10^5
Alcohol	240	8.5×10^5
Sulphuric Acid	122	5.1×10^5
Ether	84	3.9×10^5

Thermometer is an instrument for measuring the temperature of a body. A thermometer works on the expansion of a liquid (like mercury or alcohol) with temperature. Mercury is most commonly liquid which is used in thermometers.

Advantages of mercury as a thermometric substance :

(i) Mercury has uniform expansion rate

(ii) Mercury does not wet the glass

(iii) Mercury does not vaporize easily

(iv) Mercury is opaque

(v) Mercury is good conductor of heat so quickly attains the temperature of the body.

(vi) Mercury has low freezing point of $-39°C$ and high boiling point of $357°C$.

(vii) Mercury is available in pure form.

Calorimetry: Calorimetry means measurements of heat.

Principle of calorimetry: When a hot body is mixed with a cold body, the heat lost by hot body is equal to the heat gained by cold body, provided no heat is allowed to escape to the surroundings.

Heat lost = Heat gained.

Equilibrium temperature: The resultant temperature obtained by mixing a hot substance with a cold substance is called

the equilibrium temperature.

Saturated air: It is found that at any given temperature air can not hold more than a definite amounts of water vapour. When the air holds this maximum amount of water vapour. It is known as saturated air. Air is rarely saturated. It contains muchless water vapour than the maximum limit. It has been found that with the increase in temperature air can hold more water vapour.

Hygrometer: The instrument used for measuring the relative humidity of air is called a Hygrometer. To find the relative humidity of air a dry and wet bulb hygrometer is used.

LIGHT

Light: It is an agent which produces in us the sensation of sight. It, itself is invisible but makes the other objects visible. It may be defined as the radiant energy which produces the sensation of light.

Reflection: The bending of light to the first medium from the surface of separation of the two media. The rays are sent back by this process. The phenomenon of reflection of light is shown in Fig.

Refraction: The bending of light from its straight path as it enters from one medium to another.

Luminous Body: A body that emits light itself is called as luminous body. (star, sun, fire etc.)

Non-luminous body: A substance that

does not emit light itself.

Optical medium: A substance or any portion of space through which light can pass is known as optical medium. It can be solid, liquid or gas.

Homogeneous or isotropic medium: Medium possessing same optical properties in all the directions.

Heterogeneous or anistoropic medium: Medium possessing different optical properties in different directions.

Transparent body: It is a body through which light can pass easily. (air, glass etc.)

translucent body: It is the body through which light can pass only partically, so that object can be seen only indistinctly. (oiled paper)

Opaque body: It is a body which does not allow light to pass through it e.g., bricks, wood etc. No substance is perfectly transparent or perfectly opaque.

Ray of light: The path along which light

travels in a homogeneous medium is called the ray of light.

Beam of light: A shown in Fig. the group of parallel rays is known as beam of light.

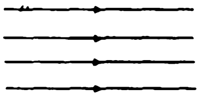


Fig. Beam of Light

Pencil of light: A group of inclined rays of light diverging from a point source or converging to another point is called a pencil of light.

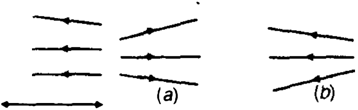


Fig.

Divergent pencil: If the rays of light are diverging from a point source so that the distance between the rays goes on increasing as they move forward, then the group is known as divergent pencil as shown in figure.

Convergent pencil: If the rays of light are converging to a point so that the distance between the rays goes on decreasing as they move forward, then the group is called convergent pencil as shown in the figure.

Reflection of light: The process of sending back the light rays which fall on the surface of an object is known as reflection of light.

Incident ray: The ray of light originating from the source and falling on the surface of a mirror.

Point of incidence: The point at which the incident ray comes in contact with the mirror.

Reflected ray: The ray of light which is sent back by the mirror is known as the

reflected ray.

Normal: The normal is a line at right angles to the mirror surface at the point of incidence.

Angle of incidence: The angle of incidence is the angle made by the incident ray with the normal at the point of incidence.

Angle of reflection: The angle of reflection is the angle made by the reflected ray with the normal at the point of incidence.

Regular reflection: When a beam of parallel light rays falls on a shining, but plane surface, the light rays are reflected back in the same order. It is regular reflection.

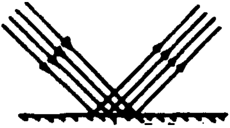


Fig. (a) Regular Reflection

Irregular reflection: When light beam falls on rough but uneven surface the light rays reflected back in many directions. This is known as irregular reflection. It gives scattered or diffused light.

Fig. (b) Irregular Reflection

Laws of reflection: The reflection of light from a plane surface like that of a plane mirror takes place according to two laws which are known as the laws of reflection.

(a) *First law of reflection.* The incident ray, the reflected ray and the normal all lie in the same plane.

(b) *Second law of reflection.* The angle of reflection is always equal to the angle of incidence.

$\angle i = \angle r$

Rotation of a plane mirror: When a plane mirror is rotated through an angle φ. The image is rotated through an angle 2φ.

Spherical mirror: is that mirror whose reflecting surface is the part of a hollow sphere of glass.

Concave mirror: A concave mirror is that spherical mirror in which the reflection of light takes place at the concave surface (or bent in surface).

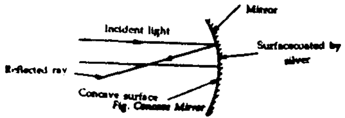


Fig. Concave Mirror

Convex mirror: As shown in Fig. in a convex mirror the spherical surface at which the reflection of light takes place is convex or the surface bulges outwards.

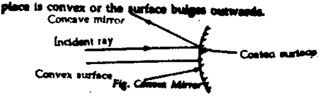


Fig. Convex Mirror

Real image: An image that can be taken on a screen.

Virtual image: An image that cannot be taken on a screen.

Sign convention used in mirrors:

(*i*) All distances are measured from the pole of the mirror.

(ii) Distances opposite to the direction of incident ray are taken as negative.

(iii) Distances in the direction of incident ray are taken as positive.

(*iv*) *If the image is real* v *is taken as* negative. If the image is virtual, v is

taken as positive.

(v) Focal length of a concave mirror is negative. The focal length of a convex mirror is positive.

(vi) Downward distances are taken as negative (-ve)

(vii) Upward distances are taken as positive (+ve)

Mirror formula: $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$$\frac{1}{\text{image distance}} + \frac{1}{\text{object distance}} = \frac{1}{\text{focal length}}$$

Relation between radius of curvature and focal length of mirror: The focal length of a concave or convex mirror is equal to half the radius of curvature.

$$f = \frac{r}{2}$$

Magnification: Ratio of the images to the size of an object.

Parallax: Apparant shift between the relative position of two objects or object and image when eye is moved sideways.

Notations used for Mirrors

f = focal length

u = distance of the object from the mirror or lens

v = distance of the image from mirror or lens

M = magnification

O = size of the object

I = size of the image

Image formed by a concave lens:

(i) *When the object is at infinity:* (see fig)

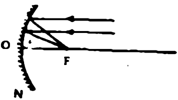


Fig.

Image formed is real inverted and point.

(ii) *Object is beyond the centre of curvature:* Image lies between F and C. The image is real, inverted and of diminished (see fig.)

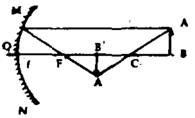


Fig.

(iii) *Object lies between C and F:* The image is formed beyond E. The image is real, inverted and enlarged in size. (see fig.)

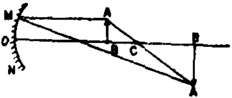


Fig.

(iv) *Object lies the centre of curvature:* The image is formed at the centre of curvature. The image is real, inverted and of same size (see fig.)

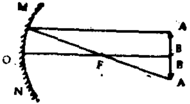


Fig.

(v) *Object lies between the pole and focus:* The image formed is virtual

erect and enlarged. The image is formed behind the mirror. (see fig.)

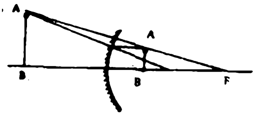


Fig.

(vi) *Object lies at principle focus:* The image is formed at infinity (see fig)

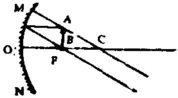


Fig.

Formation of image by a convex lens:
The image can be formed at any position.

The image is virtual erect and diminished in size. (see fig.)

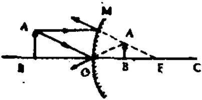


Fig.

Spherical abberation: The property of concave mirror to focus all parallel rays of a wide beam of light at a fixed point.

Convex lens: It is a converging lens as shown in fig.

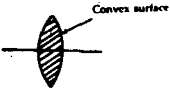


Fig.

Image formed by a convex lens:

(*i*) *When the object lies at Infinity:* The image is formed at the focus and is real, inverted and very small (see fig.)

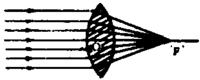


Fig.

(*ii*) *When the object lies beyond 2F:* The image formed is real but smaller and inverted (see fig.)

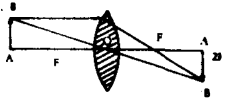


Fig.

(iii) *When the object lies at 2F:* The image formed is real but inverted and of same size (see fig.)

Fig.

(iv) *When the object lies between F and 2F:* In this position the image is formed beyond 2F. The image is real inverted and enlarged (see fig.)

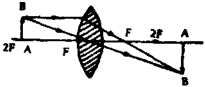


Fig.

(v) *When the object lies at F:* The image is formed at infinity (see fig.)

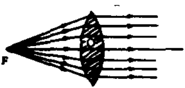


Fig.

(vi) *When the object lies between F and the optical centre:* In this position the image is formed on the same side of the lens. The image is virtual, erect and highly magnified (see fig.)

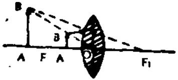


Fig.

Image formed by concave lens: The image formed by a concave lens is erect but virtual small in size and on the same side of the object as shown in fig.

Power of a lens: The ability of a lens to bend the rays passing through it is known as power.

$$\text{Power} = \frac{1}{\text{focal length in metre}}$$

$$= \frac{100}{\text{focal length in cm}}$$

It is measured in diopteres. The power of a lens of 100 cm focal length is 1 diopter.

Human eye: Human eye forms the real image on the retina. The eyeball is a nearly spherical chamber and can be

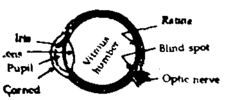


Fig.

rotated in the socket by means of it's six muscles. The outer coating called sclerotic consists of fibruous white tissues. The front part of sclerotic is transparent.

A normal eye has power of accommodation which enables objects as for as infinity and as close as 25 cm. to be focussed on retina.

Near point: The shortest distance at which an eye can see clearly is called the near point.

Least distance: It is the distance at which an eye can see clearly. It is taken as 25 cm for a normal eye.

Myopia or short sightedness: It is the defect of the eye when it cannot see far off objects clearly. Myopia occurs due to (a) elongation of the eye ball or (b) decrease in focal length of the lens. Myopia is corrected by a concave lens.

Hypermetropia or long sightedness: It is the defect of the eye when it cannot see near objects clearly. This defect can be

corrected by using a converging lense of correct focal length.

Astigmatism: It is a defect of the eye when a straight object looks as curved. It occurs due to asymmetric curvature of eye lens. This defect is corrected by using cylindrical lens.

Difference between a camera and an eye

Camera	*Eye*
The image is formed on the photo graphic plate.	The image is formed on the retina.
The objective has fixed focal length.	The focal lengths get adjusted with distance.
Camera is enclosed in light tight box to protect it from light.	Light reaches the less through the pupil.
The quantity of light is controlled by the diaphragm.	Eye lids act as diaphragm.

Photographic plate can be used only once.	The image formed on the retina is erased automatically.
Points of similarity:	
In an eye, the image is formed by a convex lens made of a transparent and flexible substance.	In a camera, the image is formed by a convex lens made of glass.
A real and inverted image is formed on the retina.	In camera, real and inverted image is formed on the photographic film.
The iris of the eye controls the amount of light entering the eye.	Thc diaphragm controls the amount of light in a camera.
The time of exposure is controlled by the eye lids.	The time of exposure in a camera is controlled by a shutter.

Astronomical telescope: As astronomical telescope is an optical device mainly used to see distant object (astronomical bodies such as stars, planets etc.)

Construction: It consists of two convex lenses. The convex lens which receives the light from the object is called the objective, the other lense which is closed to the eye is called eye piece. The distance between objective and eye piece can be arranged to obtain a sharp image.

Working: Light rays from a distant object form a parallel beam of light. This parallel beam of light is incident on the objecti. e lens, after r fraction through this objective lens, a sharp real and inverted image *AB* is formed (see fig.) at the focus of the objective.

The eye piece is so adjusted that this image *AB* lies at the focus of the eye piece, thus final image is found at infinity. The telescope is then set to be a normal adjustment.

Magnifying power of a microscope: It is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object. It is denoted by M.

$$M = 1 + \frac{D}{f}$$

where D = distance of the image from the principle pole.

Dispersion: The phenomenon of splitting of white light into its constituent colours is known as dispersion. When white light incident from the first surface enters the prism, then each colour is refracted by different angles. This is known as dispersion of light.

The angle between the two emergent rays is known as angular dispersion of these colours. The angular dispersion $\theta = \delta_V - \delta_R$.

Where δ_V and δ_R are deviations for violet and red colours.

The ratio of angular dispersion between two colours to the deviation of mean ray produced by this prism is called the disper-

sive power of material of the prism for those colours.

$$\text{Dispersive power } \omega = \frac{\delta_V - \delta_R}{\delta}$$

where δ is the deviation of mean ray δ_V and δ_R are the deviations of violet and red rays respectively.

Spectrum is the coloured pattern obtained on the screen after dispersion of light. If there is not overlapping of the colours, it is called a *pure spectrum.* A spectrometer is a device for analysis a beam of light into its component colours. The spectra is classified as follows:

- Spectra
  - Emission
    - Continuous
    - Discontinuous
      - Line
      - Band
  - Absorption

Continuous spectrum: It consists of a wide range of unseparated wavelengths. Dense hot gases and white hot solids give continuous spectrum.

Line spectrum: This spectrum consists of sharp lines of definite wavelengths. Substances in atomic states (sodium vapour lamp, mercury vapour lamps, gases in discharge tubes) give line spectrum.

Band spectrum: This spectrum consists of bright bands each having a sharp edge. Incandescent vapours in the molecular state (calcium or barium salts in the bunsen burner flame, nitrogen in molecular state in vacuum tube) give band spectra.

When light from a source is examined through a spectroscope, emission spectrum is obtained. On the other hand, when light emitted from a source is made to pass through a spectroscope, absorption spectrum is obtained.

Visible and Invisible Specturm: The spectrum which is spread from 4000 A to 7800 A and consists of red and violet

colours at its each end respectively is known as visible spectrum. The spectrum beyond violet-end of visible region is known as ultraviolet spectrum. It ranges from 4000 A to 100 A. The spectrum beyond red end of visible region is known as infra-red spectrum. It ranges from 8000 A to one mm. Ultra-violet and infra-red constitute the invisible spectrum.

Fluorescence: The phenomenon of absorption of light of one wavelength by a substance and then re-emission of light of greater wave length is known as fluorescence.

The phenomenon of re-emission of visible light even after the incident light is cut off is known as phosphorescence.

Secondary colours: Secondary colours are produced by mixing two primary colours. The phenomenon of production of secondary colours, from primary colours can be well understood by the following experiment.

Take three light torches first cover the glass of one with green cellophane, the other with red and the third with blue. Set the torches in the dark room and switch on the lights. Take the projections of these lights on the screen. The colours overlap and different shades are produced. The following colours are produced by mixing two colours.

red + green = yellow

red + blue = magneta

blue + green = cyan or peacock blue

Mixing of three primary colours in different proportions gives the entire spectrum of colours.

Unit of power of a lens: The SI unit of the power of a lens is dioptre which is denoted by the letter D.

Power of lens, $P = \frac{1}{f}$ If $f = 1$ metre

Then $P = \frac{1}{1}$

$p = 1$ dioptre

Lens formula: Lens formula is the relation between the distance u of an object the distance v of its image from the optical centre of the lens and the focal length f of the lens after applying the sign convention. i.e.,

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

(same for both concave and convex lens)

Magnification: A linear magnification produced by a lens is equal to the ratio of the image distance to the object distance.

$$m=\frac{v}{u}$$

Simple microscope: Convex lens of small focal length is a simple microscope. When an object is placed between focus and the lens and enlarged image is seen, which is virtual and erect Figure.

Convex lens is also called a reading glass, due to this property and is used for palm reading and examining signatures etc.

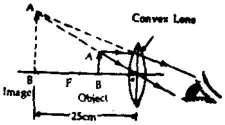


Fig.

Convex lens	Concave lens
It is thicker at the centre than at the edges.	It is thinner at the centre than at the edges.
It converges light.	It diverges light.
It has real focus.	It has virtual focus.

Refraction of light (or bending of light): The change in the direction of light when

it passes from one medium to another is known as the refraction of light. From figure the angle between the incident ray and the normal is called the **angle of incidence** ∠ AON. The angle between the refracted ray and the normal is called the **angle of refraction** ∠*N'*OB.

Cause of refraction: The refraction of light takes place on going from one medium to another because the speed of light is

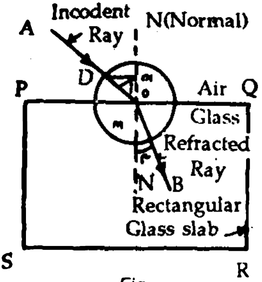


Fig.

different in the two medium. The refraction of light on going from air into glass takes place because light travels faster in air but less in glass.

Optically rarer medium and optically denser medium: A medium in which the speed of light is more is known as optically rarer medium (or less dense medium). Air is a rarer medium as compared to water or glass. A *medium in* which the speed of light is less is known as optically denser medium.

Here are two Important Rules:

(i) When a ray of light goes from a rarer *medium* to a denser medium, it bends towards the normal at the point of incidence.

(ii) When a ray of light goes from a denser medium to a rarer medium it bends away from the normal at the point of incidence.

Laws of refraction

1. The incident ray, the refracted ray and the normal at the point of in-

cidence all lie in the same plane.

2. The second law of refraction is also known as Snell's law of refraction. According to this law of refraction the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for a given pair of medium.

   That is $\frac{\sin i}{\sin r}$ = constant = μ(mu)

Refractive index of a medium,

$$\mu = \frac{\sin i}{\sin r}$$

Since the refractive index is a ratio of two similar quantities (the sines of angels), it has no units. It is a pure number.

OPTICS

If I be the intensity of illumination and Q, the amount of light falling per second upon any area A, then

$$I = \frac{Q}{A}$$

Also $I = \frac{L}{r^2}$ where r is the distance of the point from the source and L the illuminating power of the source.

Principle of Photometry: If two sources produce equal intensities of illumination on a screen then their illuminating powers are directly proportional to the squares of their distance from the screen.

i.e.,
$$\frac{L^1}{L^2} = \frac{r_1^1}{r_2^2}$$

Laws of Reflection:

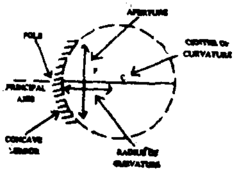
(a) The incident ray, the normal and the reflected ray lie in one plane.

(b) The angles of incidence and reflection are equal. Remember if a plane mirror rotates through a certain angle say θ, *while an incident beam* remains stationary, the reflected beam rotates through 2θ.

(c) *In the case of a plane mirror the* image lies as far behind as the object is in front of its.

(d) With a plane *mirror* the *image* formed in virtual, erect and laterally inverted.

Spherical Mirror: The inner surface is a *reflecting surface, it is called concave mirror.* If the outer-surface is a reflecting surface it is called *convex mirror. Centre of curvature* of a spherical mirror is the centre of the sphere of which the mirror is a part



If v, u, f are distance of image, distance of object and focal length respectively we have for any mirror.

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

Sign Convention: Negative x axis points are taken with their distance negative and on positive axis as positive distances. Simply the points on the positive and negative y axis

Magnification: The ratio of the size of the image to the size of the object is called linear magnification m.

$$m=\frac{v}{u}$$

The distance u, v, v are taken as p ositive or negative, according to the position of the object, position of image and focal length of the mirror.

For Concave mirror u, f are always negative and v will be negative for real image and will be positive for virtual image.

In case of convex mirror, u is negative and u, f are always positive.

Aperture: It is the diameter of the circumference of a spherical mirror

$\therefore$ Refractive index μ of a medium

$$= \frac{\text{Velocity of light in air or vacuum}}{\text{Velocity of light in the medium}}$$

(ii) *From Snell's law of refraction*

$$\text{Refractive index } \mu = \frac{\sin i}{\sin r}$$

where

i = Angle of incidence

r = Angle of refraction. (When a ray of light in a rarer medium enters into a denser medium)

(iii) If an object is placed at the bottom of a transparent medium of refractive index, it appears to be raised up n, when viewed from above. In this case,

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

(iv) $\mu = \frac{1}{\sin C}$ where *C* is a critical angle.

It is defined as the angle in a denser medium for which the corresponding angle of refraction is 90°.

(v) $\mu = \frac{\sin (A + \delta)/2}{\sin A/2}$ where *A* is the angle of prism and δ is the angle of minimum deviation.

(vi) If ${}^{a}\mu_{b}$ is the refractive index of medium 'b' w.r.t. 'a' and ${}^{b}\mu_{a}$ is the refractive index of medium *'a'* w.r.t. 'b', then

$${}^{a}\mu_{b} = \frac{1}{{}^{b}\mu_{a}}$$

or $$\frac{\mu - 1}{R} = \frac{\mu}{v} + \frac{1}{v} \quad \text{(Thinlens formula)}$$

in the case refraction from air to the medium with refractive index μ.

Power of a lens D is

$$= \frac{1}{\text{focal length expressed in metres}}$$

Silvering one surface: If one, surface of a thin lens is silvered, the rays are reflected back at the silvered portion. Generally the focal length of the effective lens is given by $\frac{1}{F} = \Sigma \frac{1}{f}$

Where f is the local length of the mirror or lens, to be repeated as many times as the reflection and refraction respectively is repreated.

(i) If a plano-convex lens is silvered at its plane surface as shown in the diagram we find rays from the object refracts first at the surface 'a' and reflects at the surface 'b' and again refracts out at the surface 'b' and

again refracts out at the surface 'a'

Then focal length of the lens say F_1 is given by

$$\frac{1}{F_1} = \frac{(\mu - 1)}{R}$$

and the focal length of the mirror F_m is given by $\frac{1}{F_m} = \frac{R}{2}$

Thus $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_m} + \frac{1}{F_1}$

$\therefore \quad \frac{1}{F} = \frac{2}{F_1}$ (It is because F_m is ∞)

Fig.

(ii) In a Plano convex lens be silvered at its convex surface thɾn proceeding as above we get

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_m} + \frac{1}{F_1}$$

$$= \frac{2}{F_1} + \frac{1}{R/2} \qquad \left(\because f_m = \frac{R}{2} \right)$$

Also $\quad \frac{1}{F} = \frac{2\mu}{R}$

(iii) In the case of a double convex lens with a convex surface of radius R_2 is silvered then proceeding as above

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_m} + \frac{1}{F_1} = \frac{2}{F_1} + \frac{2}{R_2}$$

There are two necessary conditions for totoal internal reflections :

(1) The rays should travel from a denser medium to a rarer medium

(2) The angle of incidence in a denser medium should be more than the critical angle.

Prism of small angle (thin Prism): When

the angle of prism is less than 10° the

$$\delta = (\mu - 1) A$$

Rememuer: For maximum deviation by a prism

(a) the angle of incidence must be 90° or

(b) the angle of incidence corresponding to grazing emergence.

Angular Dispersion or Angular separation of the spectrum and Dispersive Power.

If δ_v and δ_r are the deviation for the violet and red colours or wave lengths and μ_v and μ_r be the respective refractive indices, then the angular dispersion is given by:

Angular Dispersion

$$= \delta_v - \delta_r = (\mu_v - \mu_r) A$$

Dispersive Power =

$$w = \frac{\delta_v - \delta_r}{\delta} = \frac{\mu_Q - \mu_r}{\delta - 1}$$

If w and w' are the dispersive Powers of

two prisms then $\frac{w}{w'} = \frac{\delta'}{\delta}$

and δ and δ' are the mean deviations produced by two prisms.

Chromatic aberration is defined as the horizontal distance between the red and violet images formed by lens and is equal to

$$f_r - f_v = w.f$$

where f_r, f_v, f are the focal lengths for red a violet and yellow colours.

Velocity of Light

(i) *Velocity of light by Fizeau's Method:*

The velocity of light, when first eclipse of the image takes place is given by:-

$$V = 4\ mnd.$$

Where

m = number of teeth or spaces in the toothed wheel

n = Frequency or number of revolutions made per second by the toothed wheel.

d = distance between the concave mirror and toothed wheel.

For any eclipse the formula is :-

$$V = \frac{4\ mnd}{(2P - 1)}$$

where P = Number of eclipse that has occurred i.e. $P = 1, 2, 3, 4$, etc.

(ii) *Focault's Rotating Mirror Method* -

The velocity of light is given by the formula $V = \dfrac{3\pi nbd^2}{x(a + d)}$

where n = Number of revolutions made per second by the plane mirror.

d = Distance between concave mirror and revolving plane mirror.

a = Distance between plane mirror and optical centre of lens.

d = Distance between the source of light and lens.

$x =$ Shift of the image of the source.

If θ is the angle through which the revolving mirror turns and is measured in radians then

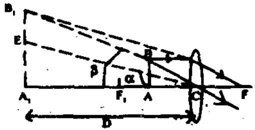
$$V = \frac{4\pi nd}{\theta}$$

OPTICAL INSTRUMENTS

Simple Microscope: A convex lens of short focal length forms a simple microscope.

Figure illustrates the ray diagram.

Its magnifying power is given by

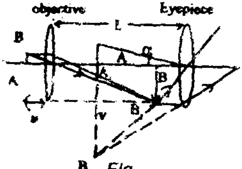


$$m = 1 + \frac{D}{f_e}$$

where D is the least distance of distinct

vision and for normal eye it is 25 cm and f_e is the focal length of eye piece.

Compound Microscope: It is used to view tiny objects. It gives a magnified image or the details of the object can be studied easily. Here the eyepiece of a comparatively longer focal length produces a vertical and magnified image of the image formed by the objective.



Fig

Fig. illustrates the ray diagram for it. Its magnification is given by

$$m = \frac{v}{u}\left[1 + \frac{D}{f_e}\right]$$

$$= m_o \times m_e$$

v distance of the real image from the object,
u distance of the object from the objective.

Also $m = \frac{L}{F}\left[1 + \frac{D}{f_e}\right]$

L = length of the tube

F = focal length of the objective.

Telescope: It is an instrument used to see clearly distant objects. Astronomical telescopes are used for seeing clearly heavenly bodies such as stars, moon, planets etc.

For normal adjustment, Let F be the focal length of the objective and f be the focal length of the eyepiece. Its magnification is given by

Magnifying Power = $\frac{F}{f}$

Mirage: While travelling on a concrete road on a hot summer day, the road at a distance appears to be covered with water.

In deserts, travellers some times see the image of an object such as a tree as if in

water. But as one approaches the region where the water appears to be, one realises that in fact there is no water at all anywhere and that it was just an illusion. This phenomenon of optical illusion is known as mirage.

Prism: It is a portion of transparent material bounded by two plane surfaces which are inclined at angle called angle of prism.

Factors on which the deviation produced depends are called (i) angle of prism (ii) refractive index of the material of the prism and (iii) wavelength of light.

If the angle of prism is more, the deviation produced is more. If refractive index of the material is higher, the deviation produced is also greater. If the wave length of light is less the deviation produced is more.

MEASUREMENTS

Unit: A unit is a suitable standard quantity either fixed by a law or agreed upon mutually, in terms of which other quantities of the same kind can be measured.

Fundamental units: A set of independent units of basis physical quantities, which can be easily obtained in terms of which units of all other mechanical quantities may be derived is called a fundamental unit. Units of mass, length and time are generally taken as fundamental units.

Derived units: Physical quantities which can be expressed in terms of fundamental quantities of mass, length and time are called derived quantities e.g., velocity, acceleration, force, energy, power, pressure etc.

Astronomical unit (A.U): The mean distance of the sun from the earth is called astronomical unit (A.U.). It is equal to about 1.496×10^{11} m.

Light year: It is a unit used to measure the distance between the earth and stars

$$1 \text{ Light year} = 365 \times 86400 \times 3 \times 10^{8} \text{ m}$$
$$= 9.46 \times 10^{15} \text{ m}$$

Micron: It is equal to 10^{-6} m or 10^{-4} cm.

Angstrom (A): It is equal to 10^{-10} metre. Thus the radius of hydrogen atom is 0.5 A.

Nanometre is preferred for writing of the wavelength of light and other radiations in nanometre (nm).

$$1 \text{ nm} = 10^{-9} \text{ m} = 10 \text{ A}$$

Fermi: It is equal to 10^{-15} metre.

The effective radius of proton is 1.2 fermi.

Parsec (Parallactic second): It is the distant that corresponds to an annual parallax of one second arc due to rotation of the earth.

$$1 \text{ parsec} = 3.26 \text{ light years}$$
$$= 3.26 \times 9.46 \times 10^{15} \text{ m}$$
$$= 3.08 \times 10^{16} \text{ m.}$$

Coherent system of units: A coherent system of units is a system based on a certain set of basic (or fundamental) units from which all derived units may be obtained by simple multiplication or division without introducing any numerical factors. S.I. system of units is a coherent system of units of all the type of physical quantities.

S.I. or International system of units: S.I. is the abbreviation of the French Systeme International D' Unite's introduced in 1960. This sytem, is of six fundamental quantities.

Fundamental Units:

Amere (A) is the fundamental unit of electric current. It is defined as that constant current which, when flowing in two straight parallel conductors of infinite length and of negligible area of cross-section and placed

one metre apart in vaccum, would produce between these conductors a force equal to (2×10^{-7}) newton per meter of length.

Metre (m) is the fundamental unit of length and is equal to 1,650, 763.78 wavelength in vaccum of the radiation emitted by the Krypton-86 atom in its transition between the states 2_{p10} and $5d_5$.

Kilogram (kg) is the fundamental unit of mass and is equal to the mass of a platinum-iridium cylinder of diameter equal to its height which is preserved in a vault at International Bureau of Weights and Measures at Severs near Paris.

Second (s) is the fundamental unit of time and is the duration of 9, 192, 631, 770.0 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of cesium 133 atom.

Kelvin (K) is a unit of themodynamic temperature. It is equal to the fraction 1/273 16 of the thermodynamic temperature of triple point of water.

Candela (cd) is the unit of luninous intensity. It is defined as the luminous intensity, in a perpandicular direction, of a surface of 1/600,000 square metre of a black body at a temperature of freezing platinum under a pressure of 101,325 newton per square metre.

The candela is approximately 0.98 of the original international candle.

S.I. Units of fundamental physical quantities

Name of the fundamental physical quantity	*Name of the S.I. unit and its symbol*
Length or Distance	meter (m)
Mass	kilogram (kg)
Time	seconds (s)
Electric current	ampere (A)
Temperature	kelvin (k)
Luminous intensity	condela (cd)
Amount of substance	mole (mol)

Supplementary Units

(a) Radian (rad): is the plane angle between the two radii of a circle which cuts off on the circumference an arc equal to the length of the radius. It should be noted that

$$\alpha \text{ (in radian)} = \frac{\text{arc}}{\text{radius}}$$

(b) Steradian (sr). It is the solid angle, which, with the vertex at the centre of a sphere, cuts off an area of the surface of the sphere, equal to that of a square having sides of length equal to the radius of the sphere. If S_n is the area cut off on the surface of a sphere of radius r, the solid angle at the centre of the sphere is given by

$$\Omega \text{ (in steradian)} = \frac{S_n}{r^2}$$

Advantages of SI units

They are more logical and coherent and are easily reproducibe

They are invariant in time because they are based on some property of atom.

This system adopts joule as the unit of energy for all forms including heat and also adopts watt as the unit of power. Thus it saves the trouble of expressing power in various other units in different branches.

As it is a rationalised system, it has all those advantages which MKSA had in the field of magnetism and electricity.

Important derived S.I. units are

Joule (*J*) is the amount of work done when the point of application of a force of 1 newton is displaced through a distance of 1 metre in the direction of the force.

Newton (*N*) is the force which produces in a mass of 1 kilogram as acceleration of 1 metre per second.

Watt (*W*) is the unit of power equal to 1 joule per second.

Coulomb (*C*) is the quantity of electric charge transported in 1 second by a current of 1 ampere.

Volt (*V*) is the difference of electric potential between two points of a conducting wire carrying a constant current of 1 ampere

when the power dissipated between these points is equal to 1 watt.

Ohm (***h***) is the resistance between two points of a conductor when a constant potential difference of 1 volt applied between these two points produces in this conductor a current of 1 ampere, the conductor itself not being the source of any e.m.f.

Farad (***F***) is the capacitance of a capacitor between the plates of which there appears a difference of potential of 1 volt when it is charged by 1 coulomb of electricity.

Lumen (***lm***) is the luminous flux emitted within unit solid angle of 1 steradian by a point source having a uniform intensity of 1 candela.

Lux (***lx***). It is the illumination of 1 lumen per square metre.

International Symbols for SI Units

Unit	Symbol	*Unit*	*Symbol*
metre	m	weber	wb
kilogram	kg	joule	J

second	s	watt	W
ampere	A	coulomb	C
kelvin	K	volt	V
candela	cd	ohm	ohm
radian	rad	farad	F
steradian	sr	henry	H
hertz	Hz	lumen	lm
newton	N	lux	lx
pascal Pressure)	Pa		

Prefix and their Symbols for Expressing Power of 10

Power of 10	*Prefix*	*Symbol*
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	Kilo	K

10^{2}	Hecto	h
10^{1}	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Dimension of a physical quantity: are the powers to which the fundamental units of mass, length and time be raised to represent it. The units of mass, length and time are denoted by [M], [L], [T]. The unit of area which is the product of length and breadth will be represented by $[L]\times[L] = L^2$.

Dimensional formula: of a physical quantity is an expression showing how and which of the fundamental unit enter into it. For example dimensional formula for a

area is $M^0L^2T^{-3}$].

Dimensional equation is an expression which indicate the relation between fundamental and derived units. For example,

$$\text{unit of speed} = \frac{\text{unit of length}}{\text{unit of time}} = \frac{L}{T}$$

$[LT^{-1}] = [M^0LT^{-1}]$. From this equation it is clear that dimension of speed are zero in mass, 1 in length and − 1 in time.

Principle of Homogeneity of dimensions: According to this principle if an equation represents a correct physical phenomenon the dimensions of all the terms on the left hand and right hand side of this equation must be the same.

Uses of dimensional equations

To check the accuracy of an equation and to establish new physical relations.

Limitations of the theory of dimensions

It gives no information about the dimensionless constants and the dimensionless variables. Method of dimensional analysis fails in case of physical relations involving

trigonometric or exponential or logarithmic functions. Method of dimensional analysis fails to establish the exact form of a physical relation if, the physical quantity depends on more than three dimensional quantities.

DIMENSIONS

Physical Quantities	*Relation with other quantities*	*Dimensions and Dimensional formula*
Length	—	$L = [M^0 L T^0]$
Mass	—	$M = [M L^0 T^0]$
Time	—	$T = [M^0 L^0 T]$
Area	Length × length	$L^2 = [M^0 L^2 T^0]$
Volume	$(Length)^3$	$L^3 = [M^0 L^3 T^0]$
Acceleration	Change in velocity/time	$= \frac{LT^{-1}}{T} = LT^{-2}$ $= [M^0 L T^{-2}]$

Physical Quantities	*Relation with other quantities*	*Dimensions and Dimensional formula*
Force	Mass × Acceleration	$= M \times LT^{-1}$ $= MLT^{-1}$
Momentum	Mass × Velocity	$= M \times LT^{-1}$ $= [MLT^{-1}]$
Velocity	Length/Time	$\frac{L}{T} = LT^{-1}$ $= [MLT^{-1}]$
Work of Energy	Force × Distance	$= MLT^{-2} \times L$ $= [ML^{2}T^{-2}]$
Power	Work/Time	$= \frac{ML^{2}T^{2}}{T}$ $= [ML^{2}T]$
Density	Mass/ Volume	$\frac{M}{L^{3}} = ML^{-3}T^{0}$

Physical Quantities	*Relation with other quantities*	*Dimensions and Dimensional formula*
Pressure	$\frac{\text{Force}}{\text{Area}}$	$= \frac{MLT^{-2}}{L^2}$ $= [ML^{-1}T^{-2}]$
Stress	Force/Area	$\frac{MLT^{-2}}{L^2}$ $[ML^{-1}T^{-2}]$
Co-efficient of Elasticity	$\frac{\text{Stress}}{\text{Strain}}$ $ML^{-1}T^2$	$= [ML^{-1}T^{-2}]$
Strain	Change in dimension/ Original dimension	$= \frac{L}{L}$ or $\frac{L^3}{L^3}$,

Physical Quantities	*Relation with other quantities*	*Dimensions and Dimensional formula*
Co-efficeint of viscosity	$\frac{\text{Force/Area}}{\frac{\text{Change in Velocity}}{\text{Change in distance}}}$	$= \frac{\frac{MLT^{-2}}{L^2}}{\frac{LT^{-2}}{L}}$ $= [ML^{-1}T^{-1}]$
Surface Tension	$\frac{\text{Force}}{\text{Length}}$	$\frac{MLT^{-2}}{L}$ $= [ML^0T^{-2}]$
Frequency	Number of vibration/ Time	$\frac{1}{T} = T^{1}$ $= [M^0L^0T^{-1}]$
Surface Energy	$\frac{\text{Work}}{\text{Area}}$	$\frac{ML^2T^{-2}]}{L^2}$ $= [ML^0T^{-2}]$

Physical Quantities	*Relation with other quantities*	*Dimensions and Dimensional formula*
Angle	Arc/Radius	$\frac{L}{L}$ = No dimension
Angular Velocity	Angle/Time	$\frac{1}{T} = T^{-1}$ $= [M^0L^0T^{-1}]$
Moment of Inertia	Mass × (distance)^2	$ML^2 = [ML^2T^0]$
Couple of Torque	Force × distance	$MLT^{-2} \times L$ $= [ML^2T^{-2}]$
Impulse	Force × Time	$[MLT^{-2}] \times [T]$ $= MLT^{-1}$

Physical Quantities	*Relation with other quantities*	*Dimensions and Dimensional formula*
Angular acceleration	Change in angular $= \frac{\text{velocity}}{\text{Time}}$	$= \frac{T^{-1}}{T} = T^{-2}$ $= [M^0L^0T^{-2}]$
Kinetic Energy	$\frac{1}{2}$ mass × (velocity)^2	$[M] \times [LT^{-1}]^2$ ML^2T^{-2}
Potential Energy	Mass× acceleration dice to gravity × height	$[M][LT^{-2}][L]$ ML^2T^{-2}
Young's Modulus	Longitudinal stress/Linear strain	$= \frac{ML^{-1}T^{-2}}{L/L}$ $= ML^{-1}T^{2}$

Error: It is the uncertainty in the measurement of the magnitude of a physical quantity.

Percentage Error:

$$\frac{\text{Absolute error}}{\text{Mean value of measurement}} \times 100$$

$$\delta a = \frac{\Delta a}{a_{mean}} \times 100\%$$

Absolute Error: It is the difference in magnitude between the value of the quantity and the individual measurement value. It is denoted by Δa.

Significant Figures (digits) In Numbers

It is the number of digits that are used to express any physical quantity precisely.

Radar: Relation for calculating distance of plane

$$d = \frac{c \times t}{2}$$

Where :

d = distance of the plane

c = velocity of radiowaves = 3×10^{8} m/s

t = time delay

Radar: can also be used to find velocity and direction of motion of the aeroplane.

Sonar: Relation for calculating the distance of the object

$$d = \frac{c \times t}{2}$$

where

d = distance of the object

c = velocity of radiowaves = 1493 m/s

t = time delay

Sonar can also provide information about shape of objects, their speed and direction of motion.

Area: The area of an object is the amount of surface it occupies. Area is a derived physical quantity. The S.I. unit of area is square meter (written in short form as m^2). A square meter is the area of a square whose each sides 1 metre.

$$1\ cm^2 = 10^{-4} m^2$$

$$1\ mm^2 = 10^{-6} m^2$$

1 hectare = $10^4 m^2$

1 km^2 = $10^6 m^2$

Area of regular figures:

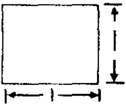


Fig.

Area of square

= $(length)^2 = l^2$

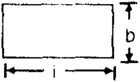


Fig.

Area of a rectangular

= length × breadth

= $l \times b$

Area of a triangle

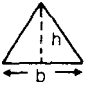


Fig.

$= \frac{1}{2} \times$ base × height

$= \frac{1}{2} \times b \times h$

Area of a parallelogram

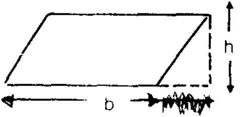


Fig.

$= \text{base} \times \text{height}$

$= b \times h$

Area of a cylinder

$= 2\pi \times \text{radius} \times \text{height}$

$= 2\pi \times r \times h$

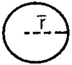


Fig.

Area of a circle

$= \pi \times (\text{radius})^2$

$= \pi r^2$

Fig.

where pi, $\pi = \frac{22}{7}$

and r = radius of circle

Area of a sphere

$= 4\pi \times (\text{radius})^2$

$= 4\pi r^2$

[If each side of a regular figure is increased n times, then its area increases by n^2 times.]

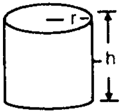


Fig.

Area of irregular figure: The irregular body whose area is to be determined is placed on the graph paper and its boundary is traced on a graph paper with a pencil.

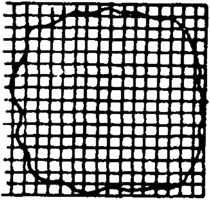


Fig.

Body is then removed from the graph paper and the number of small squares falling inside the boundary are counted. While counting those squares which are greater than half or equal to half are taken as full squares whereas those squares which are less than half are neglected.

Volume: of an object is the amount of space it occupies.

The S.I. unit of volume of cubic metre which is written as m^3. A cubic metre is the volume of a cube whose each side is 1 metre.

$$1cm^3 = 10^{-6}m^3$$
$$1mm^3 = 10^{-9}m^3$$
$$1\ km^3 = 10^9m^3$$

Volume of regular solids:

Volume of a cube

$= (\text{length})^2$

$= l^2$

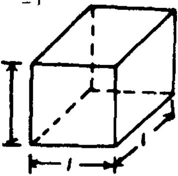


Fig.

Volume of a rectangular block

$= \text{length} \times \text{breadth} \times \text{height}$

$= l \times b \times h$

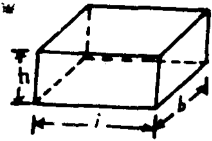


Fig.

Volume of a sphere

$$= \frac{4}{3}\pi r^2$$

where $\pi = \dfrac{22}{7}$

and r = radius of a sphere

Volume of a cylinder

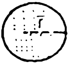


Fig.

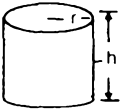


Fig.

$= \text{Area of base} \times \text{height}$

$= \pi r^2 h$

where $\pi = \frac{22}{7}$

r = radius of cyliner

h = height of cylinder

If each side of a regular body is increased n times then volume of the body increases n^2 times.

Volume of Irregular Solids: The volume of a solid body of irregular shape such as stone, metal key is found by experiments

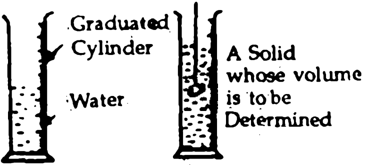


Fig.

by the displacement method by using the fact that "when a solid body is dipped in water, it displaces water to its own volume

Mass: of a body is the quantity of matter contained in it and is measured by comparing its mass with standard masses or weight. This comparison is made by using a physical balance and a set of standard weights.

Weight: of a body on the earth is the force with which the earth attracts the body towards its centre.

The weight of a body is maximum of the equator and minimum on the poles

Difference between mass and weight.

Mass	Weight
Mass is a scalar quantity having magnitude only.	Weight is a vector quantity having magnitude as well as direction.

Mass of a body is the quantity of matter contained in it.	Weight of a body is the force with which it is pulled by the earth.
Mass of a body is constant and does not change from place to place.	Weight of a body is not constant. It changes from place to place due to change in gravitational force.
Mass of a body is never zero.	Weight of a body can be zero (when gravitational attraction is zero).
Mass of a body is measured by a physical balance (beam balance)	Weight of a body is measured by a spring balance.
The S.I. unit of mass is kilogram (kg)	The S.I. unit of weight is newton (N).

Density: of a substance is defined as its mass per unit volume.

$$\text{Density} = \frac{\text{Mass of the substance}}{\text{Volume of the substance}}$$

In symbol $\rho = \frac{M}{V}$ where (rho) ρ = Density, M = mass, V = Volume.

Density is a **scalar quantity**. The S.I. unit of density is kilogram per cublic metre which is written as kg/m^2 or $kg\ m^{-3}$.

Relative density (Specific quantity): The relative density of a substance is the ratio of its density to the density of a reference substance taken as standard. Usually water is taken as the reference substance for solids and liquids and hydrogen for gases.

Relative density of a substance

$$= \frac{\text{Density of the substance}}{\text{Density of the water}}$$

An relative density is a ratio of two similar quantities (weights) it has no units.

Measurement of time: Any process which repeats itself at regular time intervals can be used for the measurement of time. For example, the oscillations (or swings) of a pendulum occur at regular intervals and this fact has been used in the construction of pendulum clocks.

The Simple Pendulum: The arrangement of small metal ball (called bob) swinging at the lower end at the long end of a thread is called a simple pendulum.

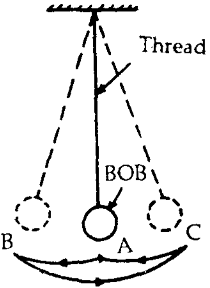


Fig.

Time period is the time required to complete one revolution. The time required by the bob to move from one extreme (C) to another extreme (B) and back to (C) is known as time period. (see fig.)

The simple pendulum the movement of bob from A to B, from B to C and back to A constitute one swing or oscillation.

The time period T of a simple pendulum is given by the equation

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where l = length of the pendulum

and g = acceleration due to gravity.

From the above formula it is found that

(i) time period is directly proportional to the square root of length.

(ii) time period is inversely proportional to the square root of acceleration due to gravity (g).

(iii) time period is independent of mass of the bob

(iv) time period is independent of the material of bob.

Effective length of the pendulum: The distance between the point of suspension and centre of gravity of the bob is known as effective length of the pendulum.

Frequency: is defined as the number of vibrations made by a vibrating particle in one second.

or $$n = \frac{1}{T}$$

Where n = frequency of vibration

T = time period

Second's pendulum: A simple pendulum whose time period is 2 seconds is known as a second's pendulum.

Restoring force: When a body is displaced from its mean (equilibrium) position, a force comes into action that tries to bring it back to its original position. It is known as restoring force.

Graph between L and T: The time period T of a simple pendulum is given by

$$T = 2\pi \frac{\sqrt{L}}{g}$$

or $$L \propto T^2$$

The graph between T and L^2 is shown in Fig.

The graph between L and T^2 is a straight line.

Maximum and minimum speeds of the bob: is maximum at the mean position and minimum at the extreme positions.

WAVES

Wave: The different shaped vehicle which is responsible for transmission of energy from one place to another through a medium without any translation of medium is called a wave.

When waves is dropped into the pond of water, circular concentric water waves are produced on the surface of water. These waves carry energy in all directions.

Waves in a rope is another example of wave motion.

These can be classified into transverse waves and longitudinal waves.

Physical quantity transferred by wave motion. Energy

Mechanical waves. The waves originated in an elastic material (air, steel and water) are called mechanical waves.

Properties which are responsible for transmission of mechanical waves in a medium. Elasticity and density of the medium.

Transmission of mechanical waves through vacuum. The mechanical waves can not be transmitted in the vacuum. It is necessary to have a material medium to transmit mechanical waves.

Characteristics of wave motion. The wave motion is form of disturbance which travels in a medium, i.e., motion of particles of the medium.

It is only the energy of the disturbance that travels forward, the particles of the medium simply vibrate about their mean positions.

The velocity of the wave motion is different from the velocity with which particles of the medium vibrate about their mean position.

The motion of each particle begins a little latter than that of its predecessor, i.e., there is always a constant phase difference between two neighbouring particles.

At the mean position, the energy of the particles is wholly kinetic. At the extreme positions the energy is wholly potential.

The waves can undergo reflection, refraction diffraction dispersion and interference.

The velocity of particles of the medium is different at different position of its vibration whereas the velocity of the wave is constant throughout a given medium.

Pulse: It is a wave of short duration. It can also be said as a wave of single disturbance.

Longitudinal waves: The particles of medium vibrate to and fro in longitudinal waves (Sound waves are longitudinal waves).

Transverse waves: The particles of medium vibrate at right angles in

transverse waves. Propagation of waves through a rope is an example of transverse wave.

Characteristics of wave motion: In a wave motion,

(i) each particle takes energy from the preceding particles and transmits it to the next.

(ii) only energy is transferred

(iii) all the waves travel with the same speed in the same medium.

Mechanical Waves: The waves that require mechanical medium for their propagation are called mechanical waves. Propagation of sound is an example of mechanical and longitudinal wave. Mechanical waves cannot travel is vacuum.

Amplitude: In a wave motion, amplitude is the maximum displacement of the particles of the medium from their mean position. In Fig. AM is the amplitude of the wave. It is also equal to CN to EG.

Wavelength: is the distance between two nearest particles which are in the same state of vibration. OD shows the wavelength of a wave in Fig.

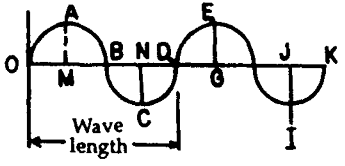


Fig.

Time period (T): It is defined as the time taken by any particle of the medium to complete one oscillation. (It is always measured in seconds.)

Frequency (f): Number of vibrations per second is called frequency. Mathematically $f = \frac{1}{T}$

where T is in seconds.

Wave velocity: Also known as velocity of wave (c). It is the distance travelled by the wave is one second. Mathematically.

$$c = \lambda \times f$$

where c = velocity of wave

λ = wavelength of the wave

f = frequency of the wave

Explanation of Pulse: In a pulse the medium oscillates for a short while, and then returns to its original position of equilibrium.

In a single wave pulse, oscillation takes place only once. Wave pulse is only of short duration and not repetitive.

(1) Fig. A shows a stretched string.

(2) Fig. B shows origination of pulse

(3) Fig. C shows propagation of pulse

(4) Fig. D shows completion of pulse.

Periodic waves: Continuous waves or repetitive waves. Fig. E shows continuous wave disturbance. Such waves in string are produced by continuous disturban-

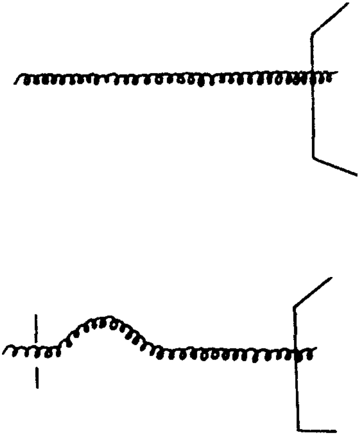
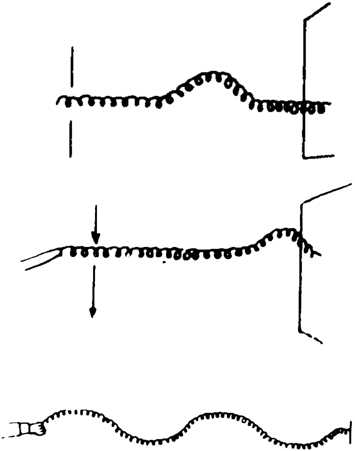


Fig.



ces. Vibration of a tuning fork produces continuous wave train in a medium.

Conditions of transverse waves: In addition to various condition transverse waves require the following conditions for propagation.

(1) The medium should posses inertia property.

(2) The medium should be elastic.

(3) The frictional resistance between the particles of the medium should be negiligibly small.

Examples of transverse wave: Water waves on the surface of water are transverse in nature.

Transverse waves are produced in a string by continuous vibrations of the hand.

Motion from one bob to the adjoining bob is transmitted by transverse propagation.

Difference between the transverse and longitudinal waves.

Transverse waves	*Longitudinal waves*
1. Here the particles of the medium vibrate up and down at right angles to the direction of propagation of wave.	1. Here the particles of the medium vibrate to and fro about its mean position along the direction of propagation of wave.
2. The crests and trough are for-med.	2. Compression and rarefractions are formed.
3. Transverse waves can be polarized	3. Longitudinal waves can not be polarized.
4. Ripples in water, waves in string of sitar	4. Sound wave in air, wave produced in compressed spring.
5. These waves can propagate through solids and liquids.	5. These waves can travel through all the mediums i.e. solids, liquids and gases.

Elastic waves: The waves that require a material medium for propagation are called elastic waves Sound waves are elastic waves as they cannot travel in vacuum.

Wave motion: is defined as the form of disturbance which travels through a medium due to repeated periodic motion of particles of the medium about their mean position, the energy being handed over from one particle to another.

Progressive Wave Motion.

(1) It can only travel through an elastic medium.

(2) The particles of the medium do not travel forward but simply vibrate about their mean position.

(3) A particle vibrates a little later than the preceeding particle.

(4) The velocity of wave and velocity of particle are not the same.

Waves carry Energy: Waves carry energy. It can be verified by the following experiments.

(i) Drop a stone in a pond of water. It is seen that ripples are produced on the water surface. If a leaf lies over the surface of water, it also moves up and down. It shows waves carry energy.

(ii) Fig. Below (a) shows a string AB. End A is held in the hand and end B is fixed. When jerk is given to the hand, vibrations as shown in Fig. (b) are produced in the string.

Fig. (a)

Fig. (b)

The kinetic energy of the hand goes to the string, as a result, ripples are produced in it. The propagation of energy takes place from A to C, C to D, D to E, E to F, F to G and finally from G to B.

Difference between transverse waves and longitudinal waves:

1. The particles of the medium vibrate up and down at right angle to the direction of propagation of the waves.	1. The particles of the medium vibrate to and for along the direction of propagation of the waves.
2. Alternate crests and troughs are formed.	2. Alternate regions of compression and rarefraction are formed.
3. At a crest, particles are at rest, having	3. At compression, the particles move in

moved to extremely uppermost positions, while at a through, particles are at rest having moved to extreme downward positions.	the direction of the wave while at rarefraction, particles move in a direction opposite to the direction of the wave.
4. Transverse waves are formed in a medium possessing rigidity and cohesion.	4. Longitudinal waves are formed in a medium which possesses volume velocity.
5. The wave form is a sine curve.	5. The waveform represents a medium of varying densities and pressures; but can be converted into a sine curve, with the usual convention.

Other types of waves: In addition to above discussed waves there is another very important class of waves. These waves

are known as electromagnetic waves and can travel through vacuum. A few examples of such waves are radio waves and light waves.

Comparison between progressive and stationary waves.

1. Progressive waves appear to be traveling from one point to another.	1. Stationary waves appear to be standing.
2. It consists of only one type of waves.	2. A stationary wave is a combination of two progressive waves travelling in the opposite directions, that is it is a combination of an original wave and its reflected wave

3. It consists of crests and troughs or compression and rarefactions.	3. It consists of nodes and antinodes.
4. A progressive wave is a disturbance which moves from one place to another.	4. It is a distance between two fixed points and cannot move beyond these points.
5. The amplitude of vibration of each particle in a progressive wave is the same.	5. In a stationary wave, different particles vibrate with different amplitudes. At anode the amplitude of vibration is zero but at antinodes it is the maximum.

6. In a progressive wave, there is a continuous changes of phase from particle	6. In stationary wave, all the particles within any loop are in the same phase. They
to particle.	are 180° out of phase with particles in the neighbouring loops.

Phase difference between two points in a wave motion: This term indicate how much the two particles (at the two points)

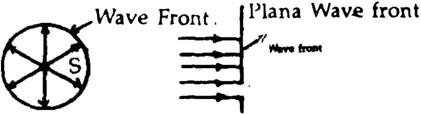


Fig.

are out of step with each other, i.e., by how much angle or by how much time one is ahead of the other.

Wave front: is the locus of all points of the medium in the same phase, i.e., in the same state of vibration.

Ray. A straight line perpendicular to wave front at any instant represents a ray.

Water waves: The waves travelling on the surface of water are neither purely longitudinal nor purely transverse and are called water waves.

Coherent waves: Waves travelling in the same direction in a medium with same velocity and the same period, having no phase difference or a constant phase difference in between them are called coherent waves.

Reflection and refraction of sound waves. Sound waves obey the ordinary laws of reflection and refraction

i.e. $\angle i = \angle r$ and

$$\frac{\sin i}{\sin r} = \text{constant} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

Intensity: The intensity of a plane progressive wave is directly proportional to

square of the amplitude of the wave.

$$I = \frac{1}{2}\rho c\,(2\pi v a)^2 = 2\rho c \pi^2 v^2 a^2$$

i.e., Intensity α (Amplitude)^2.

Velocity amplitude: A plane wave is represented by

$$\xi = a \sin \frac{2\pi}{\lambda}(vt - x)$$

Particle velocity

$$\frac{d\xi}{dt} = \frac{2\pi v a}{\lambda} \cos \frac{2\pi}{\lambda}(vt - x)$$

The term $\frac{2\pi v a}{\lambda}$ is called velocity amplitude and represents the maximum velocity of the particle.

Acceleration amplitude: Particle acceleration is given by

$$\frac{d^2\xi}{dt^2} = -\left(\frac{2\pi v}{\lambda}\right)^2 a \sin \frac{2\pi}{\lambda}(vt - x)$$

This term $\left(\frac{2\pi v}{\lambda}\right)^2 a$ is called accelera-

tion of amplitude and represents the maximum acceleration of the particle.

Velocity of sound in gases: The velocity of a longitudinal wave in a gaseous medium depends upon its volume elasticity and its density

$$v = \sqrt{\frac{E}{\rho}}$$

where E is the coefficient of volume elasticity of the gas and p its density.

Newtons's formula for the velocity of sound in a gas: Newton assumed that the compressions and rarefractions in a gas takes place under isothermal conditions (i.e, temperature of the gas remains constant) so that the coefficient of volume elasticity of a gas is equal to the normal pressure P of the gas. According to him the velocity of the sound 'v' in a gas is given by,

$$v = \sqrt{\frac{P}{\rho}}$$

For air the value of $\rho = 0\ 001293\ gm/cm^3$

at 273K and the normal pressure $P = 76 \times 13{\cdot}6 \times 981$ dynes so that

$$v = \sqrt{\frac{76 \times 13{\cdot}6 \times 981}{0{\cdot}001293}} = 280 \text{ m/s}.$$

By the actual value is $v \approx 332$ m/s at 273 K. This discrepancy in velocity was corrected by Laplace.

Laplace's correction: Laplace stated that the change in volume and pressure of the layers of the medium due to sound waves are addiabatic (i.e. total quantity of heat in the system remains constant) and not isothermal.

He gave the formula as

$$v = \sqrt{\gamma p/\rho}$$

where γ is the ratio of specific heat at constant pressure to the specific heat at constant volume.

For air $\gamma = 1{\cdot}41$, substituting this value in (i) we get, $v = 331{\cdot}6$ m/s.

Factors which defect the velocity of sound in air (or a.'y other gas).

Effect of pressure. The change of pres-

sure have no affect on the velocity of sound in air (or any other gas).

Effect of density. If the density of a gas is increased the velocity sound in it decreases

Effect of temperature. The velocity of sound in air increases on raising the temperature.

Effect of humidity. Sound travels faster in humid air and slower in dry air.

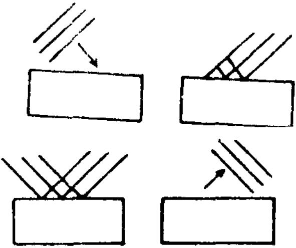


Fig. Various stages of reflection

Reflection. Sound waves are also reflected from wall, a water surface inside a wall, roof of a *room*, *etc*. In daily life we come across many important phenomena of this

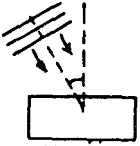


Fig. (a) The incident wave making an angle with normal.

reflection like echoes, reverberation in building etc. Reflection of plane wave is shown

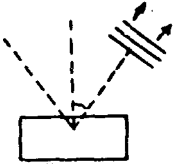


Fig. (b) The reflection ray making some angle with the normal.

below in figure.

Sound waves created in water, light etc. all fallow laws of reflection. This figure shows that the angle of incidence is same as angle of reflection

Fig. (a) The incident an angle with normal, Fig (b) The reflection ray making some angle with the normal

- ***Stationary waves:*** Stationary wave is formed when two waves of same frequency travelling in opposite directions are superimposed on each other. This is a particular phenomenon of interference of waves. In stationary waves there is no flow of energy in either direction The medium gets split up into segment, each segment vibrating up and down a whole. There are some particles which are permanently at rest, called nodes, 'N' while others which suffer maximum displacement from the mean position are called antinodes.
- ***Longitudinal stationary waves:*** These can be produced in a long flexible spring

or in air column inside a closed end on open end pipe.

Electro Magnetic Waves: These can be produced by rapid vibration of current in a conductor. If the resistance of conductor is very small, then the frequency of oscillation is given by.

(f) or $$\eta = \frac{1}{2\pi\sqrt{LC}}$$

The change in the magnetic intensity at any point at a distance x in the field, lags behind the change in current by a time $\frac{x}{c}$, where C = velocity of propagation of electromagnetic wave.

If variation in current is given by

$$I = I_0 \sin \omega t$$

Then the magnetic intensity (H) at any point at distance x from conductor is given by

$$H = H_x \sin\omega\left(t - \frac{x}{c}\right)$$

where

H_x = the intensity of magnetic field in the direction x corresponding to steady current I_o.

The A.C. in the conductor is thus associated with an electric field given by

$$E \propto \frac{dH}{dt}$$

or $$E = E_x \cos \omega \left(t - \frac{x}{c} \right)$$

An electron oscillating with a frequency 10^3 cycles/sec produces electromagnetic wave of wave length.

$$\lambda = \frac{c}{n} = \frac{3 \times 10^8}{10^3} m = 300 \text{ km}.$$

It shows that the charge should oscillate over a distance of 300 km so as to radiate sufficient amount of energy.

Spectrum of electromagnetic waves:

Frequency (Hz) →

10^4 10^6 10^8 10^{12} 10^{14} 10^{16} 10^{18} 10^{20} 10^{22}

Wavelength (m)

$10^{4}\ 10^{2}\ 10^{0}\ 10^{-2}\ 10^{-4}\ 10^{-6}\ 10^{-8}\ 10^{-10}\ 10^{-12}\ 10^{-4}$

Radio Micro ↓ X-rays γ-rays

waves waves U.V.

Visible light

Visible range is comprised of radiations with frequency/wave length range as under

Frequency

$$3.84 \times 10^{14}\ HZ < f < 7.69 \times 10^{14}\ HZ$$

Wave length

$$7.80 \times 10^{-7}\ m > \lambda > 3.90 \times 10^{-7}$$

(Red) (violet)

Polarization: In case of transverse waves, the displacement of the particles of the medium is perpendicular to the direction of propagation. If displacement of the particles is in many directions, the wave is known as unpolarized.

When the displacement pattern of a transverse wave lie in a single plane, the wave is called plane polarized.

Diffraction: The bending of wave round the

corners of an obstacle is called diffraction of waves. When plane wave come across an obstacle or surface having a small opening in it the wave continue to propagate around the obstacle or through the opening after bending. The wave spread out around the obstacle or the opening on the other side and the wave pattern gets modified (it become semi-circular). Diffraction depends on the relation between the wave length and the width or diameter *d* of the obstacle or the opening

MOTION

Motion: A body if changes its position with respect to another. Then it is called Motion. Every body know that even earth is not stationary. However, for all practical application earth is assumed as stationary. Thus a body can be said in motion if it changes its position with respect to earth.

Motion can be further classified into (a) uniform motion and (b) non-uniform or variable motion.

Uniform motion: If a body covers equal distances in equal intervals of time, it is said to be moving with uniform motion or the motion of the body is uniform.

Non uniform motion: if a body covers unequal distances in equal intervals of

time, it is said to be moving with non-uniform or variable motion.

Origin: Any arbitrarily selected fixed point, with respect to which the position changes.

Distance: The actual length covered by a body during the whole journey. It is a scalar quantity. In SI units it is measured in metres (m).

Displacement: It can be defined as the distance travelled by a body in a particular direction. It is a vector quantity. In SI units, it is measured in metres (m).

Speed: The rate of change of movement (distance) is called speed. It is a scalar quantity. In SI units it is measured in metres per second (m/s). Mathematically.

$$\text{Speed} = \frac{\text{distance (s)}}{\text{time (t)}}$$

Average Speed: It is the distance travelled by body per unit time. Mathematically.

Average Speed =

$$\frac{\text{Total distance travelled by the body}}{\text{Time taken by the body to cover the total distance}}$$

Uniform Speed: If a body covers equal distances in equal intervals of time it is said to be moving with uniform speed.

Scalar Quantity: Physical quantities possessing magnitude only are known as scalar quantities. Area length, volume, mass and speed are scalar quantities.

Vector Quantities: Physical quantities that can be represented completely by magnitude and direction are known as vector quantities. Velocity, acceleration, weight and force are vector quantities.

Velocity: The rate of change of distance in a particular direction is called velocity. It is a vector quantity. Its unit is m/s Mathematically

$$\text{Velocity}(\vec{v}) = \frac{\text{Displacement }(\vec{S})}{\text{time }(t)} \text{ m/s}$$

Variable Velocity: If a body, moving in a particular direction, covers equal distan-

ces in equal intervals of time, it is said to be moving with uniform velocity. Alternatively a body is said to be moving with uniform speed if its speed and direction does not change with time.

Variable Velocity: A body is said to be moving with variable velocity if it covers unequal distances in equal intervals of time. A body is said to be moving with variable velocity if (a) the direction of motion changes, or (b) speed changes or (c) both direction and speed changes.

SI Units

Physical Quantity	SI Units	*Symbol*
Distance	Metre	m
Displacement	metre	m
Mass	kg	kg
Time	second	s

Speed	metres per second	ms^{-1}
Velocity	metres per second	ms^{-1}
Acceleration	metres per second per second or metre per second squared	ms^{-1}
Angular velocity	radians per second	rad s^{-1}

Acceleration: The rate of change of velocity is known as acceleration.

Acceleration ($\vec{a}$) =

$$\frac{\text{Change in velocity}(\vec{v} - \vec{u})}{\text{time } (t)}$$

Uniform Acceleration: If the velocity of a moving body increase by equal amount in equal intervals of time, it is said to be moving with uniform acceleration. For example a stone falling from the top of a tower comes down with uniform acceleration of $9{\cdot}81 m/s^2$. Fig. shows

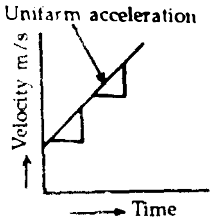


Fig.

uniform acceleration of a body on velocity-time graph.

Variable Acceleration: If the velocity of a moving body changes by unequal amounts in equal intervals of time.

Then it is said to be moving with variable acceleration.

Retardation: If the final velocity of a body is less than the initial speed, then it is known as declaration and the body is said to be undergoing retardation. For all

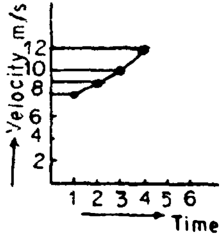


Fig.

mathematical calculations, it is taken as acceleration with minus sign.

Graphs: Graphs are used for conveniently representing the given data on two mutually perpendicular axis. For the properly plotted graphs, we can find out those values which are not given on the data.

Thus graphs are more informative. Selection of proper axis plays a vital role for plotting the graph. Commonly used practice is to use x-axis for independent

quantity and y-axis for dependent quantity.

Average Velocity: Is defined as the velocity of a moving body per unit time. Mathematically

Average Velocity =

$$\frac{\text{Total distance travelled}}{\text{Total time taken}}$$

or $$V_{avc} = \frac{S}{t}$$

In the case of a uniformly accelerated motion

$$V_{avc} = \frac{u + v}{2}$$

where u = initial velocity,

and v = final velocity.

Suppose a train travels 6000 m in 300 seconds. Then the average velocity of the train.

$$\frac{6000}{300} = 20 \text{ m/s}$$

Angular Velocity: The rate of change of

angular displacement as known as angular velocity. The velocity of a body moving in a circle is measured in radians/seconds (rad s^{-1}).

It is denoted by Greek letter omega (ω)

or Angular velocity =

$$\frac{\text{angular displacement in radians}}{\text{time taken}}$$

or

$$\omega = \frac{\theta}{t}$$

where θ = angular displacement

Derivation of the equations of motion:

Consider the motion of a body, moving with uniform acceleration.

Let x = initial velocity of the body

y = acceleration of the body

then

velocity of the body at the end of one second = $x + y$

velocity of the body at the end of two seconds = $x + 2y$

velocity of the body at the end of three seconds = $x + 3y$

velocity of the body at the end of t seconds = $x + yt$

(i) *thus* $v = x + yt$

where v = final velocity of the body.

Since the body is moving with uniform acceleration,

thus average velocity of the body.

(ii) $V_{avc} = \frac{x + v}{2}$

From equation (*i*), we get $t = \frac{v - x}{y}$

But distance (S) covered by the body.

S = average velocity x time

or $$S = \frac{v + x}{2} \times \frac{v - x}{y} = \frac{v^2 - x^2}{2y}$$

(iii) or $v^2 - x^2 = 2y^s$

From equation (*i*), we get $v = x + yt$

Also $S = \left(\frac{v + x}{2}\right) \times \text{time} = \left(\frac{x + v}{2}\right) t.$

Substituting the value of v in the above equation, we get

(iv) or $S = \frac{x + x + yt}{2} \times t = xt + \frac{1}{2}yt$

Motion under Gravity: When a body falls towards the earth, its velocity goes in increasing continuously. The body is said to be falling under gravity.

When a body falls under gravity, it continuously gains acceleration = g.

Thus the equations of motion of a body falling under gravity are written as

$$v = x + gt$$

$$S = x + \frac{1}{2}gt^2$$

and $$v^2 - x^2 = 2gs$$

In these equations, y is replaced by g.

When body goes away from the earth, then its velocity goes on decreasing continuously. The value of g is taken as negative for such cases for solving the problems of physics.

Thus $v = x - gt$

$$S = ut - \frac{1}{2} gt^2$$

and $v^2 - x^2 = -2gs$

LAWS OF MOTION

First law : A body continues to remain in state of rest or uniform motion in the same direction in a straight line unless acted upon by some external force.

Second Law : The rate of change of momentum of a body is directly proportional to the implied force and takes place in the direction of the force.

$$F = m \times a$$

Third Law : To every action there is equal and opposite reaction.

$$F_1 = -F_2$$

FORCE AND ACCELERATION

Force: Force is agency which produces or tends to produce, destroys or tends to destroy, the state of rest or uniform motion of a body.

It also changes the shape and direction of a body. It SI system it is measured in Newtons (N).

For example a ball on a table moves when it is pushed. It shows that the ball needs a force to change its state of rest.

Types of Forces:

In nature we observe a number of forces.

1. Muscular force is exerted in lifting heavy bodies.

2. Force of friction helps us to move on smooth roads.
3. The magnetic force of attraction is responsible for an iron rod attracted by a magnet.
4. The gravitational force pulls all bodies towards the centre of the earth.
5. There are forces of attraction like cohesion and adhesion between molecules.
6. There are very short range forces like nuclear forces that keep the nuclear particles together.

The ability of a body to communicate motion to another body by impact depends on both its mass and velocity and this ability of the body is called its momentum. The momentum of a body is measured by the product of its mass and velocity.

Momentum: It can **be defined as** the quantity of motion **possessed by a** body. It is a vector quantity.

Mathematically, momentum = mass x velocity

$$M = m \times u$$

The units of momentum is kg m/s. It is a vector quantity.

Balanced Force: If a number of forces acting on a body do not produce any change in speed or shape, then these forces are known as balanced forces. Balanced forces do not change the speed of a body.

Unbalanced Forces: Unbalanced forces produce change in speed or shape of a body. If the resultant of forces acting on a body is not zero, it is said to be under the action of unbalanced forces.

Inertia: Inertia is a measure of mass of a body. Greater the mass of a body, greater will be its inertia or vice versa. When any vehicle starts suddenly, the passenger falls backward. It is due to inertia property of the body.

Impulse: The product of force and time for which it acts is known as impulse. It is a vector quantity.

Impulse = Force x time.

The units of impulse is Ns.

Newton's laws of motion.

(i) *Newton's first law motion.* A body at rest will remain at rest and a body in motion will continue in motion in a straight line with a uniform speed, unless it is compelled by an external force to change its state of rest or of uniform motion

(ii) *Newton's second law of motion.* The force acting on a body is directly proportional to the product of the mass of the body and the acceleration produced in the body by the action of the force, and it acts in the direction of motion. Suppose a force 'F' acts on a body of mass 'm' and produces an acceleration 'a' in the body According to second law of motion.

Force α mass $\times$ acceleration

or $F \alpha m \times a$

$$F = k \times m \times a$$

Where k is a constant. The value of k in S.I. units is 1, so that the above equation

becomes

$$F = m \times a$$

Unit of force. The S.I. unit of force is newton which is denoted by N. A newton is that force which when, acting on a body of mass 1 kg produces an acceleration of 1 m/s^2 in it.

(iii) *Third law of motion.* Whenever one body exerts a force on another body, the second body exerts an equal and opposite force on the first body. The force exerted by first body on the second body is known as 'action' and the force exerted by the second body on the first body is known as reaction. It should be noted that action and reaction are just forces. According to Newton's third law of motion: *To every action there is an equal and opposite reaction.*

Momentum. The momentum of a body is defined as the product of its mass and velocity

$$\text{Momentum} = \text{mass} \times \text{velocity}$$

$$M = m \times v$$

Momentum is a **Vector quantity**. The S.I. unit of momentum is kilogram-meter per second which is written as *kg-m/s* or *kg* ms^{-1}.

Another definition of Newton's second law of motion: The force applied to a body is directly proportional to the rate of change of momentum which it produces in the body.

Impulse of a force. An impulsive force is that force which acts on a body for a very short time. The impulse acting on a body is equal to the product of force acting on the body and the time for which it acts.

Impulse = force × time

Impulse = $F \times t$

The S.I. unit of impulse is **newton-second** which is written as *Ns*.

Impulse is also equal to mass × change in velocity.

Law of Conservation of momentum: It states "momentum can neither be created nor destroyed but can be changed from one form to another." Al-

ternatively, it states, "the total momentum of any group of objects remains the same unless they are acted upon by some external unbalanced force".

Total momentum before collision = total momentum after collision. *Recoil of a gun* : When a gun fires, the bullet moves forward and the gun is kicked back. This backward motion of the gun is called the 'recoil of a gun'.

Recoil velocity. The recoil velocity of the gun is given by the expression

$$v = \frac{mV}{M}$$

where

m = mass of the bullet

M = mass of the gun

V = Velocity of the bullet

v = velocity with which the gun recoils.

Moment arm. The moment arm of a force F about pivot point A is the perpendicular distance L between the line of action of the force and the pivot point A.

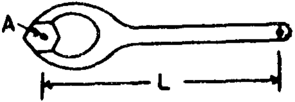


Fig.

Moment of a force (Torque). This is defined as the product of the force and moment arm (or force arm)

Torque = force × moment arm

The moment of torque is a **vector quantity**. The S.I. unit of moment or torque is newton-meter which is written in short as *Nm*.

Difference between momentum: Moment is the turning effect produced in the body.

Moment = force × distance (Nm)

Momentum is the total motion possessed by the body.

Momentum = mass × velocity (kg m/s)

Principle of moments. The condition for

rotational equilibrium of a body is known as the principle of moments which can be defined as. When a body is in rotational equilibrium, that is when a body does not rotate under the action of a number of external forces, the sum of the anticlock-wise moments of all forces about any point is equal to the sum of the clockwise moments of the forces about the same point.

Anticlockwise moment = force × force arm

$$= F_1 \times OA$$

Clockwise moment = $F_2 \times OB$

Sum of anticlockwise moments = sum of anticlockwise moments.

$$F_1 \times OA = F_2 \times OB$$

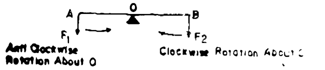


Fig.

Couple: A pair of equal and opposite parallel forces acting on a body, which

produces rotation in the body is known as a couple

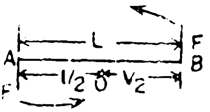


Fig. A Couple

(a) Moment of force F (acting at A) about point O

$$= \text{force} \times \text{force arm}$$

$$= F \times OA = F \times \frac{l1}{2}$$

(b) Moment of force F (acting at B) about point O

$$= \text{force} \times \text{force arm}$$

$$= F \times OB = F \times \frac{l}{2}$$

For getting the moment of the couple as a whole, we should add the above two couples.

Moment of a couple

$$= F \times \frac{l}{2} + F \times \frac{l}{2}$$

$$= F \times l \text{ newton-meter}$$

Moment of a couple = one of the forces × couple arm. Couple cannot be balanced by a single force. When the second player kicks it, the ball moves towards the first player. It means the force can change direction of motion of the body.

It can change the shape of an object. Press the tyre of your cycle with your thumb. It is seen that the tyre is pressed a little and its shape changes. It means, the force can change the shape of an object.

Formulae of Motion

(i) Force = mass × acceleration

(ii) Momentum = mass × velocity

(iii) Newton is a unit of force. One newton is that much force which produces in a mass of 1 kg an acceleration of 1 m/s^2.

(iv) The SI unit of momentum is kgm/s.

(v) The SI unit of velocity of m/s.

(vi) The SI unit of acceleration is m/s^{-2}.

(vii) When two forces acting on two bodies in contact are equal and opposite, then one of the forces is known as action, and the other force is known as reaction.

Friction: Keep a book on a table as shown in fig. Apply a very small force in the direction of the book remains stationary.

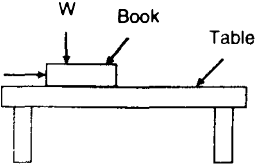


Fig.

It means some opposing force has come in action at the surfaces of contact.

This force is known as force of friction.

Friction always opposes motion of one body over the surface of another body.

Laws of Friction:

1. Friction opposes relative motion between two surface in contact and is always parallel to the surface of contact.
2. Friction depends on the nature of the two surface in contact i.e. nature of materials, surface finish, surface films, lubrication of surface, temperature and the impurities between the two surfaces.
3. Friction is independ of the area of contact between the two surfaces.
4. Friction is directly proportional to the normal reaction acting on the body.

Types of Friction: There are two types of friction.

(i) Friction in unlubricated surfaces.

(ii) Friction in lubricated surfaces.

Friction can also be classified in the fol-

lowing manner

(i) Sliding friction.

(ii) Rolling friction.

Sliding Friction: When one surface slides across another, the friction between them is described as sliding friction.

Rolling friction: When one surface rolls along another, the friction between them is described as rolling friction. On the basis of stages of motion, friction can be classified as static friction and dynamic or kinetic friction.

Static Friction: It is the force of friction that acts on a static body when it is in rest position inspite of the fact that some force is being applied on it.

Dynamic or Kinetic Friction: It is the force of friction that comes into play when a body is in a state of steady motion on the surface of another body.

Limiting Friction: It is the force of friction that comes into play when a body just slides over another body. It is equal to the maximum value of static friction.

Friction a Necessity: Friction plays an important role in our daily life. In many cases friction is useful and we wish to retain, whereas in other cases friction is harmful and we want to reduce it.

While walking friction between the ground and the shoes prevents us from slipping. It is difficult to walk on ice, because friction is small. Without friction motion cannot be conveyed by belts from the motor to the machine, brakes cannot be applied to cars, the knots could not be tied, a match is lighted by friction.

On the other hand friction increases the work necessary to operate machinery. It causes wear and tear and it generates heat which damages machines.

Means of Reducing Friction:

1. ***Polishing:*** Friction between two surfaces can be reduced to polishing them.

2. ***Bearings:*** The rolling friction is less than the sliding friction. The free wheels of a cycle, motor car, shafts

of motors, dynamos etc are provided with ball bearings to reduce friction considerably.

3. ***Lubricants:*** A lubricant is a substance which forms a thin layer between two surfaces in contact and reduces friction. It also fills the depression present in the surfaces in contact and smoothen them. In light vehicles or machines, oils like three in one are used as lubricants. In heavy machines, grease is used. In auto-mobiles 2-T oil pumped into various parts with high pressure to reduce the friction and thus increase the mobility.
4. ***Stream Lining:*** Auto-mobiles and aeroplanes are streamlined to reduce the friction due to air.

Laws of Friction:

1. Friction opposes relative motion between two surface in contact and is always parallel to the surface of contact.

2. Friction depends on the nature of the two surface in contact i.e. nature of materials, surface finish, surface films, lubrication of surface, temperature and the impurities between the two surfaces.
3. Friction is independ of the area of contact between the two surfaces.
4. Friction is directly proportional to the normal reaction acting on the body.

CIRCULAR MOTION

Rotational motion: A body is said to possess motion of rotation if (i) all the particles of the body move in circles with their centres lying on the axis of rotation and (ii) all the position vectors sweep out the same angle in a given time interval.

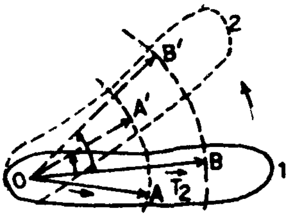


Fig.

Angular displacement: of a particle moving in a circle may be defined as the angle swept out by the position vector in a given time interval.

The S.I. unit of measurement of angular splacement is **radians.**

A radian is the angle subtended at the entre of a circle by an arc of length equal to he radius of the circle. θ (in radian) $= \frac{S}{r}$.

One radian $= \frac{360}{2\pi} = 57{\cdot}3$

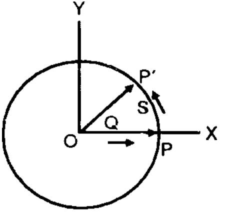


Fig.

Angular velocity: is defined as the rate of change of angular displacement of a body.

If a body describes a small angle $\Delta\theta$ in small interval of time Δt then angular velocity ω is given by the relation,

$$\omega = \frac{\Delta\theta}{\Delta t}$$

The unit of angular velocity is radians per second (rad s^{-1}).

Time period: The time period of a body revolving about a fixed point is defined as the time taken by it to complete one full revolution. It is denoted by T.

Frequency: The frequency of a body revolving about a fixed point (or a fixed axis) is defined as the number of complete revolutions made by it in a unit time.

Frequency it denoted by symbol 'v'.

Relation between time period and frequency:

$$v = \frac{1}{T} \quad \text{or} \quad T = \frac{1}{v}$$

Relation between angular velocity, time period and frequency:

$$\omega = 2\pi \times \frac{1}{T} = 2\pi v.$$

Instantaneous angular velocity: of a particle at any given instant is given by the limit approached by the above ratio $\frac{\Delta\theta}{\Delta t}$ as Δt approaches zero. Instantaneous angular velocity.

$$\omega = \underset{\Delta t \to 0}{Lt} \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}$$

Angular velocity is a vector quantity. The direction of angular velocity vector of a Particle rotating in a circle is represented by an arrow drawn along the axis of rotation, the length of the arrow being proportional to the magnitude of the vector quantity.

Relation between linear and angular velocity: $v = \omega r$

The magnitude of the linear velocity of a particle moving in a circle is the product of the angular velocity and the distance of the

particle from the axis of rotation. In vector form it is written as $\vec{v} = \vec{\omega} \times \vec{r}$

Centripetal force: is the force that compels a body to keep moving in a circular path with a constant speed and is directed along the radius of the circle towards its centre

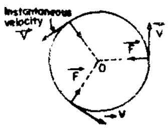


Fig.

Expression for centripetal force: This is denoted by the following formulae,

$$F = \frac{mv^2}{r} = mr\omega^2 = 4\pi^2 rv^2$$

Where *m* is the mass of a particle moving

along a circle of radius r with a uniform speed v.

centrifugal force: A centrifugal force is defined as the force of reaction exerted by a body moving uniformly along a circular path on the external agent which is providing the centripetal force, by virtue of its constant tendency to travel along a straight line path.

The centrifugal force acts along the radius but in the outward direction.

Heliocentric theory of planetary motion: According to the heliocentric theory of copernicus, the sun is considered as steady at the centre of the universe and all heavenly bodies revolve around it in circular orbits.

Kepler's laws of planetary motion:

(i) *Law of orbits.* Each planet revolves around the sun in an elliptical orbit.

(ii) *The law of areas.* The radius vector from the sun to the planet sweeps out equal areas in equal times *i.e.*, the

speed of the planets varies in such a way that the line joining the sun and a planet sweeps out equal areas in equal times. Thus our earth moves with greater velocity when it is close to the sun.

(iii) *The law of periods.* The square of the period of any planet about the sun (T^2) is proportional to the cube of the planet's mean distance from the sun (r^3). In other words $\frac{T^2}{r^3}$ is constant for all the planets.

Newton's law of gravitation: According to newton every particle of matter in this universe attracts every other particle with a force which is directly proportional to the product of the masses of the particles and inversely proportional to the square of the distance between them,

$$F \alpha \frac{m_1 m_2}{d_2} \text{ or } F = G \frac{m_1 m_2}{d_2}$$

where m_1 and m_2 are the masses of two

bodies and d is the distance between them. G is a universal gravitational constant. The value of G is 6.67×10^{-11} $Nm^2\,kg^{-2}$. Dimensions of gravitational constant G are $[M^{-1}\,L^{-3}\,T^{-2}]$.

Relation between gravitational constant (G) and acceleration due to gravity: (g)

$$g = \frac{GM}{R^2} \quad /g = 9.8\ ms^{-2}$$

$$G = 6.67 \times 10^{-11}\ Nm^2\,kg^{-2}.$$

$$R = \text{radius of earth} = 6.38 \times 10^{6}\ m$$

$$M = \text{mass of earth}$$

Gravitational field: The space surrounding the attracting particle within which its gravitational force of attraction may be experienced (or detected) is known as gravitational field of that particle.

Intensity of gravitational field: The gravitational field intensity at a certain point in the gravitational field due to a given mass is the force experienced by a

unit mass placed at the point. In SI system gravitational field in tensity is $N\ kg^{-1}$ or ms^{-2}.

Gravitational potential energy: The energy associated with a body as a result of its position in the gravitational field of the other is called gravitational potential energy.

The gravitational potential at a point in the gravitational field of a given mass is the amount of work done in bringing a unit mass from infinity to that point. The expression for gravitational potential energy at a point is

$$\phi = \frac{GMm}{r}$$

The -ve sign indicates that work is done by the gravitational force of attraction.

Satellite: Now come to satellite. A satellite is a body which revolves round a planet without consumption of fuel or energy of its own.

Orbital velocity: The velocity of about 8 kms^{-1} which is given to an artificial satel-

lite a few hundred kilometre above the earth's surface so that it may start circling the earth is called orbital velocity.

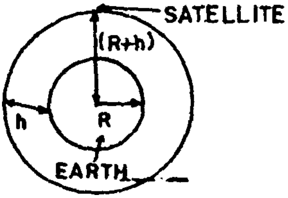


Fig.

Expression for orbital velocity,

$$v = R\sqrt{\frac{g}{R+h}}.$$

For a sattelite orbiting close to the earth $h = 0$ so orbital velocity is given by $v = \sqrt{gR}$.

Time period of a satellite is the time taken by it to come one revolution. It is given by

$$T = \frac{2\pi}{R}\sqrt{\frac{(R+h)^3}{g}}$$

Time period in terms of density is

$$T = \sqrt{\frac{3\pi\,(R+h)^3}{GR^3\rho}}$$

Velocity of escape: It may be defined as the least velocity with which a projectile must be projected in order that it may escape the earth gravitational pull. The escape velocity is given by the expression $v = \sqrt{2gR}$.

Rigid body: A perfectly rigid body is that which cannot be deformed. It can be said that position of different particles in a rigid body are fixed and their relative positions do not change even in motion.

Moment of inertia: of a rigid body, about a given axis of rotation is the sum of the products mr^2 taken for all the particles constituting the body, where m is mass of a particle and r its normal distance from the axis of rotation. $I = \Sigma mr^2$. Moment

of inertia is a scalar quantity. Its unit is kg m^2 and dimensions are $[ML^2]$. Moment of inertia of a body about a given axis of rotation depends upon the following two factors:

(i) Mass of the body and

(ii) Distribution or configuration of the particles of the body with respect to the axis of rotation.

Moment of inertia in terms of rotational kinetic energy: Moment of inertia $I = 2 \times$ *Rotational kinetic energy.*

Radius of gravitation: is defined as the distance from the axis of rotation at which if the whole mass of the body is concentrated, its moment of inertia about the axis is the same as that with the actual distribution of mass.

$$K = \sqrt{r_1^2 + r_2^2 + r_3^2 + \ldots\ldots + r_n^2}$$

Angular Momentum: of a rigid rotating body about a given axis is the vector sum of the moments of linear momenta of all the particles constituting the body about

that axis. Angular momentum is a vector quantity.

Torque: The torque of a force about an axis is measured by the product of the force and the perpendicular distance of its line of action from the axis of rotation. Torque is generally denoted by $\vec{\tau}$. The torque τ of a force $\vec{F}$ acting at a distance $\vec{r}$ from the axis of rotation is given by the relation $\vec{\tau} = \vec{r} \times \vec{F}$. It is vector quantity. The unit is (Nm) and its dimension are $[ML^{-2} T^{-2}]$.

Relation between angular momentum and torque:

$\tau = \frac{dL}{dt}$. Torque acting on a rotating body is equal to the rate of change of its angular momentum with time.

Expression for the work done by a torque: Work done by a torque (or couple) = Torque × angular displacement.

GRAVITATION

Types of forces: The various types of *forces in nature has been classified into* the following categories.

(i) mechanical force
(ii) gravitational force
(iii) electrical force
(iv) magnetic force
(v) frictional force

Gravitation: All objects possessing mass have the property of gravitation.

Gravitation is the force of attraction between any two objects of this universe. A *chair lying in a room attracts all other* objects including the earth.

Gravity: It is the force of attraction between the object and the earth.

Newton's law of Gravitation: Everybody in this universe, attracts every other body, with a force, which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Mathematically

$$F \alpha \frac{m_1.m_2}{d^2}$$

or $$F = G\frac{m_1.m_2}{d^2}$$

where m_1 and m_2 are the mass of two bodies and d_1 is the distance between them.

G is a constant known as universal gravitational constant.

The gravitational constant G, between the sun and earth is 6.67×10^{-11} Nm/kg^2.

Acceleration due to gravity: It is the acceleration with which a body falls freely. It is independent of mass of the body.

The value of acceleration due to gravity is not constant at all parts on the earth's surface. However, for practical purposes the value of g is 9.81 m/s^2. It is denoted by g.

Mass: The quantity of mattar contained in a body is known as its mass. It is a scalar quantity, and is measured in kg.

Weight: The force with which a body is attracted towards the earth is called its weight.

The weight of a body $W = mg$, where m is the mass of the body.

Centre of gravity: is a point where the whole weight of the body is supposed to be acting.

(a) Centre of gravity of a uniform road lies at its mid point.

(b) centre of gravity of a circle or sphere lies at its centre.

(c) centre of gravity of a square lies at the intersection of its diagonals.

(d) centre of gravity of a hollow cylinder lies at the common axis.

(e) centre of gravity of a rectangle or parallelogram lies at the intersection of diagonals.

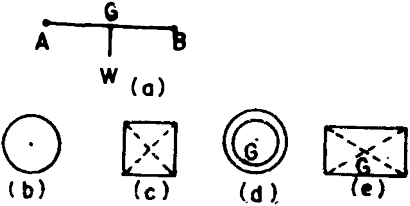


Fig. Centre of gravity of some common laminas

Weightlessness: is the state of a body, when no gravitational force acts on it. It has been proved that a person in space feels weightlessness.

Projectile: A body moving in atmosphere and is not being propelled by any fuel is called a projectile. The motion of a stone, thrown with velocity *u* in the horizontal

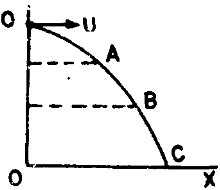


Fig.

direction as shown in Fig. The path OABC of the stone is called a Projectile

Calculating the value of g: Newton's Law of Gravitation can be applied in the following manner to calculate the value of g.

Let M_e = mass of the earth

m = mass of an object

R = radius of the earth

F = force with which the earth attracts the object. From Newton's Law of Gravitation, we get

$$F = G.\frac{M_e \times m}{R^2} \qquad ...(i)$$

Also F is equal to weight of the body

or $$F = mg \qquad ...(ii)$$

From equations (i) and (ii), we get

$$mg = G.\frac{M_e \times m}{R^2}$$

or $$g = G.\frac{M_e}{R_2}$$

The above equation proves that g is directly proportional to M_e and G, while it is inversely proportional to the square of radius R. Since it is independent of m, every body falls with the same acceleration towards the earth.

Newton's Third law of Gravitation: Newton's third law of motion is also applicable to law of gravitation. The gravitational force of attraction between two bodies is mutual. A freely falling stone acelerates towards the earth. This is due to gravitational force exerted by the

earth. In fact stone also attracts the earth towards it. However, acceleration produced in the stone is noticeable while in the earth in negligible.

Vertical distance of fall of the moon in 2 days.

Let M_e = mass of the earth

M_m = mass of the moon

R = distance between the earth and moon

F = force of attraction

thus $$F = G\frac{M_e . M_m}{R^2}$$

From Newton's second law of motion, the acceleration

$$a = \frac{F}{M_m} = \frac{G.M_e}{R^2}$$

Also distance of fall $S = \frac{1}{2}at^2$

Fall of moon in 2 days

$$S = \frac{1}{2} \cdot \frac{GM_c}{(60R)^2} \times (2 \times 24 \times 3600)^2$$

$$= \frac{1}{2} \times \frac{1}{3600} \times \frac{GM_e}{R^2} (2 \times 24 \times 3600)^2$$

$$= \frac{1}{2} \times \frac{1}{3600} \times g (2 \times 24 \times 3600)^2$$

$$= \frac{1}{2} \times \frac{1}{3600} \times 9.81 (2 \times 24 \times 3600)^2$$

$= 40642$ km.

Galileo's Experiments: Galileo dropped two stones of and unequal masses from the top of tower of Pisa and observed that both the stones reached the ground at the same instant. By this experiment he concluded that acceleration of the freely falling object does not depend on the mass of the object.

Guinea and Feather Experiment: Newton took a long glass tube as shown in Fig. In the first case he dropped a guinea and feather at the same time (from A).

He observed that guinea came to the bottom much earlier than feather. In the

second case he created complete vacuum in the tube. He again dropped the guinea and feather at the same instant. Thus he observed that both the guinea and feather came down at the same time. He concluded that in the absence of air, all bodies fall towards the earth at the same rate with uniform acceleration. This acceleration is called acceleration due to gravity (g) and does not depend upon the mass or shape of the object. He calculated the value of g as $9.81\ m/s^2$.

ENERGY

Energy: It is the capacity to do work. Energy is required for cooking, running an engine, launching a turbine, propelling a ship etc. In fact the uses of energy are numerous and is needed in everyday life.

The units of energy are the same as that of work *i.e.* Joule (J). The various forms of energy are heat, mechanical, chemical, electrical, and *nuclear*.

Joule: is the amount of work done by one newton force to move a body through one metre.

Machine: is a device that is capable of doing some useful work when energy is supplied to it at some convenient point.

Power: The rate of doing work is called power. It is measured in watt.

Watt: The rate of doing of one joule of work per second is known as watt.

$$\text{Watt} = \frac{\text{Joule}}{\text{Second}}$$

1 kilowatt = 1000 watts

Horse power: The consumption of energy at the rate of 746 watts per second is equal to one horse power.

or 1 H. P. = 746 watts.

Engine: An engine is a device used to convert heat energy into mechanical energy. Steam engine or locomotive or electric converts heat energy into mechanical energy, to transport passengers and luggage.

When water is heated, it is converted into steam. The volume occupied by steam is much larger as compared to the volume of same amount of water.

It is also capable of exerting greater pressure on the walls of the container. When steam under pressure is forced into the cylinder, it exerts pressure on the piston, and pushes it and expands.

This movements of the piston is used for running a locomotive or steam engine. The burning fuel heat the gases. As such increase in volume of gases takes place. The increased volume of gases, exert pressure on the piston to do useful work.

Some uses of energy

(i) Wind mills are used for lifting water from the ground for agricultural purposes. It utilises the energy of wind to do useful work. It can also be used for production of electricity.

(ii) Solar energy is used to cook food, boil water (solar boilers) and production of electricity (solar cells).

(iii) Water wheels convert the hydraulic energy to electrical energy.

(iv) Water wheels are used for rotating wheels of a potter.

(v) Wind energy is used for mining.

Internal combustion engine: In an internal combustion engine fuel is injected into the engine and ignited. Due to ex-

pansion of heated gas, the piston moves inside the cylinder to do useful work.

Steam engine: Steam engine is an external combustion engine. In steam engine steam is produced outside the engine, and then forced inside the cylinder to convert it into mechanical work.

The working of a steam engine is described above in *Engine.*

Wind mill: A wind mill consists of a number of vanes mounted on the stand. The lifting pump in fitted inside the water pipe. Due to velocity of wind, kinetic energy is imparted to the vanes and vanes start rotating. The rotation of vanes move the pump up and down. Due to valve fitted inside the water pipe, water is lifted upwards to do useful work.

Water wheel: is a device that converts kinetic energy for flowing water into electricity.

Limitations of wind mill and water wheel: Winds do not blow at sufficient speed at all times. Similarly water currents are not

available at suitable speeds throughout the season. The energy possessed by wind is also limited and non-uniform. Thus wind mills and water wheels are not commercially useful for the production of electrical energy.

Principle of a machine: A machine is used to do useful work. A lever as shown in Fig. is the simplest type of a machine and is used extensively for lifting heavy loads.

input = Output

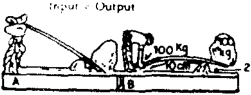


Fig.

When an effort P is applied at end B of the lever, load W is lifted upwards. In this case.

$$\text{Input} = P \times y$$

Where y = arm of the lever on the effort side

Also output = $W \times x$

Where x = arm of the lever on the load side

According to principle of the machine

$$P \times y = W \times x.$$

Suppose we lift a load of 100 kg by a lever 110 cm long. If x = 10 cm and y = 100 cm, then effort required to lift the load of 100 kg can be calculated as below by using the relation,

$$P \times y = W \times x$$

or $\quad P \times 100 = 100 \times 10$

or $\quad P = 10$ kg

Thus an effort of 10 kg can lift a load of 100 kg.

Conservation of energy of a freely falling body: Law of conservation of energy states that, "energy can neither be created nor destroyed but can be

changed from one form to another."

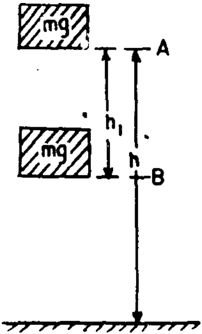


Fig.

Consider a body of mass m lying at a height h from the ground, as shown in Fig.

Potential energy of the body = mgh

The body is at rest at A, thus *K.E.* of the body is zero. Also initial velocity $u = 0$

Thus total energy of the body at A

$$= K.E. + P.E. = O + mgh = mgh \quad ...(i)$$

Consider that the body starts falling. And after some time it is at point. B.

Let h_1 = height of its fall from A to B.

The Potential energy of the body at point

$$B = mg(h - h_1)$$

$$K.E. \text{ of the body } = \frac{1}{2}mv^2$$

$$v^2 - u^2 = 2gS$$

$$v^2 - 0^2 = 2g.h_1$$

$$v^2 = 2g.h_1$$

$$K.E. \text{ of the body} = \frac{1}{2}mv^2 = \frac{1}{2}m \times 2gh_1$$

$$= mgh_1$$

Thus total energy at B =

$$mg(h - h_1) + mg.\ h_1 = mgh. \quad ...(ii)$$

From equations (i) and (ii) it is proved that total energy of the body is same. Similarly it

can be verified that total energy of the body on the ground = *mgh*

It varifies the law of conservation of energy

Joules experiment of mechanical of mechanical equivalent of heat: Mechanical equivalent of heat is defined as the amount of work done to raise the temperature of unit mass of water through 1 °C

He repeated his experiment many times and confirmed his law. He found that 4186 Joules of mechanical energy is required to raise the temperature of 1 kg of water through 1 °C

Heat Energy and Mechanical Energy: Energy can neither be created nor destroyed. But it can be changed from one form to another. Practically it has been seen that whole of available mechanical energy can be converted into heat energy. But the whole of available heat energy cannot be converted into mechanical energy

Mechanical Energy → heat energy

Heat energy → Mechanical energy + unstable heat energy. Unstable heat energy is the energy that remains in the form of heat and is not convened into heat

Engines that were first designed were able to convert only 10% of heat energy into mechanical energy. However, now a days improved engines are used. The efficiency or output of these engines is only 40%.

The remaining 60% of heat energy goes as waste. It is not possible to convert 100% heat energy into work.

Energy needed for different processor:

The amount of energy needed for different processes is shown below

Energy needed for different processes

Process	Amount of energy needed
Work done by the heart in pumping blood.	Approx. 1 J per heart beat.

Energy required to lift 1 kg by 1 m.	9.81 J, say 10 J approx.
Energy obtained by burning 1 litre of petrol.	37 MJ (37,000,000J).
Energy required for boiling a cup of milk.	Approx. 7.5 KJ.

Kinetic Energy: It is the energy possessed by a body by virtue of its motion. Mathematically,

$$K.E. = \frac{1}{2} mv^2$$

where, m = mass of the body.

v = velocity of the body

Potential energy: It is the energy possessed by the body due to its position.

$$P.E. = m.g.h.$$

where m = mass of the body.

g = acceleration due to gravity.

h = height of the body above the reference point.

Mechanical Energy: The sum of potential energy and kinetic energy is known as mechanical energy.

Mechanical energy = $K.E. + P.E.$

Escape Velocity: It is the minimum velocity with which a projectile must be projected vertically upwards so that it overcomes the earth's force of attraction and escapes into the atmosphere.

Conservation of energy: As already stated energy has many forms such as mechanical energy, heat energy, light energy, electrical energy, etc. one form of energy can be converted into another.

(i) In a steam engine, heat energy is converted into mechanical energy.

(ii) In battery chemical energy is converted to electrical energy.

(iii) In an electric bulb, electrical energy is converted into heat and light energies.

(iv) In a motor, electrical energy is converted into mechanical energy.

(v) In a dynamo, mechanical energy is converted into electrical energy.

Law of conservation of energy: The total energy of a closed system is constant. It can neither be created nor destroyed, but can be converted into other forms.

Uses of Kinetic Energy: Kinetic energy is the energy of the body by virtue of its motion A moving object is capable of doing work in a variety of ways.

A few examples of kinetic energy are given below.

(i) Falling water from a dam is used for producing electricity.

(ii) A bullet fired from a rifle moves at high velocity. It can damage the objects placed in its path.

(iii) Winds are capable of running a wind mill. A wind mill is used for taking out water from the wells.

Use of Potential Energy: The energy possessed by a body by virtue of its position of shape is known as potential energy.

Some work is required to raise a stone above the ground level.
When the same stone is released it falls downward. During its downward journey it is capable of doing work. A few example of potential energy are given below.

(i) A compressed spring can do work, when compressive force is removed from it.

(ii) The hands of a clock move with the help of springs.

Measurements of Kinetic Energy: Consider a body of mass m at rest.

Let Initial velocity of the body, $u = 0$

Force applied = F

Acceleration = a

Time of application of the force, $t = 0$,

Let S = distance moved by the body in time t.

From Newton's second law of motion.

$$F = m \times a = m \times \frac{v}{t} \quad (\because u = 0)$$

Distance covered by the body

$$S = \text{average velocity} \times \text{time}$$

$$= \frac{u + v}{2} \times t = \frac{v}{2} \times t$$

Now $K.E.$ = work done = Force × distance

$$= F \times S$$

$$= \frac{m \times v}{t} \times \frac{v \times t}{2} = \frac{1}{2} mv^2$$

Measurement of Escape Velocity: Escape velocity is the velocity with which a particle must be projected upwards, so that it escapes out of the earth's gravitational force of attraction.

Let v = escape velocity of the particle.

M_e = mass of the earth

G = Gravitational constant

m = mass of the rocket

The kinetic energy of projection $= \frac{1}{2} mv^2$

The kinetic energy of projection must be

more or at the most equal to work done in moving the body from the surface of the earth to infinity.

Gravitational force between the earth and the object.

$$F = G.\frac{M_e.m}{Re^2}$$

The work done by the rocket is the kinetic energy of the rocket.

or $$\frac{1}{2}mv^2 > G.\frac{M_e.m}{Re^2}$$

or $$v^2 > 2G.\frac{M_e}{Re^2}$$

or $$v > \sqrt{\frac{2GM_e}{Re}}$$

or $$v > \sqrt{2Re.g}$$

or $$v > \sqrt{2 \times 64 \times 10^5 \times 9.81}$$

$$v > 11.2 \times 10^3 \text{ m/s}$$

$$v > 11.2 \text{ km/s}.$$

SOLIDS

Solid. It is that state of matter in which its atom and molecules are strongly bound, so as to preserve their own shape and volume.

Crystalline solid is one which has regular and periodic arrangement of atoms or molecules in three dimensions.

Amorphous solid. is one which has not a periodic arrangement of atoms.

Difference between crystalline and amorphous solids.

Crystalline solids	Amorphous solids
The atoms or molecules in these solids are arranged in a regular and repeated long range order.	The atoms or molecules in an amorphous solid are not according to any definite order, with no long range order of atoms or molecules.

A crystalline solid has a sharp melting, since all the bonds between atoms are equally strong.	An amorphous solid does not have a sharp melting point because all the bonds between the atoms are not equally strong.
Crystalline solids are anisotropic *i.e.* their physical properties like thermal conductivity, electrical conductivity, refractive index etc. are different along different directions.	Amorphous solids are isotropic *i.e.*, their physical properties are the same in all directions.
Some crystalline solids are sodium chloride, diamond, lead etc.	Some amorphous solids are glass, rubber, plastics etc.

Crystal lattice. A crystal lattice is purely a geometrical conception, consisting of a periodic arrangement of points, such that placing different atoms (or group of atoms) on these points, we obtain the actual crystal.

Unit cell. Is the smallest closed figure formed by the smallest number of lattice

point which when repeated over and over again in all the directions, forms the actual lattice itself.

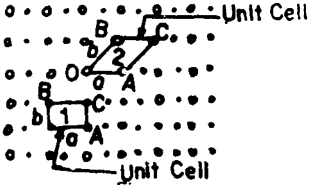


Fig.

Co-ordination number of unit cubic cell. The total number of atoms which act as the nearest neighbours of a particular atom in a unit cell is its defined as its **co-ordination number.**

Atomic packing factor. It is defined as the ratio of the volume occupied by the atoms in a unit cell to the volume of the unit cell.

Atomic radius. The atomic radius is half the distance between the centres of two neighbouring atoms of the same kind.

Characteristics of cubic cells

Characteristics	sc cell	*bcc cell*	*fcc cell*
Unit cell volume (a = b = c)	a^3	a^3	a^3
No. of atoms per unit cell	1	2	4
Co-ordination number	6	8	12
Atomic packing factor	$\frac{\pi}{6}$	$\frac{\sqrt{3}}{8}a$	$\frac{\sqrt{2}}{6}\pi$
Atomic radius	$\frac{a}{2}$	$\frac{\sqrt{3}}{4}a$	$\frac{a}{2\sqrt{2}}$

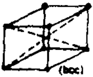
Space lattice in cubic system. There are three types of cubic system

(i) Simple cubic (sc) lattice. is the simplest type of structure in which atoms like position only at the corners of each unit cube.

(ii) *Body* centred cubic (bcc) lattice has lattice points at the corners of each

unit cell plus one lattice point at the centre of each unit cell.

(SC)



(a) (b)

Fig. (c)

(iii) Face centred cubic (fcc) lattice has one lattice point at the centre of each face besides having lattice points at

the corners of each unit (cubic) cell

Characteristics of cubic cells. (i) Volume of unit cell (ii) Number of atoms per unit cells (iii) co-ordination number of unit cell (iv) Atomic packing factor (v) Atomic radius.

Assumptions made in the determination of the characteristics of cubic cells.

(i) These sphere have the same size

(ii) All the atoms of a solid are hard and impenetrable and

(iii) These sphere touch one another while lying at various lattice points

Volume of unit cubic cell. All the three types of cubic cells, we have $a = b = c$, therefore the volume of the unit cubic cell is given by $V = a^3$.

Number of atoms per unit volume.

(i) (sc) In simple cubic structure there are eight corner atoms and each corner atom is shared by eight surrounding cubes. Therefore share of

each cube $= \frac{1}{8}$ of each corner atom.

Hence in a simple cubic structure the number of atoms per unit cell $= \frac{1}{8} \times 8 = 1$ atom

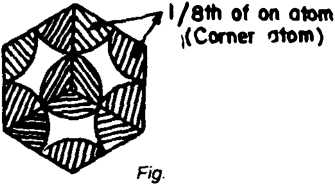


Fig.

(ii) (bcc). There are eight atoms and one at each corner and one centre atom. Out of eight corner atoms each atom is shared by a cube. Therefore the number of atoms per unit cell in body centred cubic structure is

$$= \frac{1}{8} \times 8 + 1 = 1 + 1 = 2$$

(iii) *(fcc). In this structure eight corner* atoms are shared by eight surrounding cubes and each of the six face centred atoms is shared by two adjacent cubes.

Total number of atoms in fcc

$$\text{unit cell} = \frac{1}{8} \times 8 + \frac{1}{2} \times 6 = 1 + 3 = 4$$

Chemical bond: The attraction between the atoms of a molecule which is responsible for its stable state is called a chemical bond.

Types of bonding in solids: (i) **Ionic bonding**. An ionic bond is one which is formed by the complete transference of one or more electrons from the valency (outermost) shell of an atom to the valency shell of the other atom so as to acquire the electronic configuration of the nearest noble gases.

The atom which looses electrons becomes *a positive ion* and one which gains them becomes *negative ion*. For ex-

ample, when atoms of Na and Cl are brought together, one electron of sodium is transferred to chlorine atom leaving there Na+ and CL- ions.

Cohesive energy of an ionic crystal: is the energy required to transform the crystal into isolated ions. The higher the cohesive energy, the more stable is the crystal.

Properties of ionic crystals.

(i) Their heats of vapourisation is very high

(ii) They have high cohesive energy so that their melting points are very high.

(iii) They are hard and brittle and

(iv) They are poor conductors of electricity in solid state.

Covalent bond or covalent linkage is said to be formed when two atoms combine by sharing of electrons in their outermost shell so as to acquire a stable configuration.

Diamond is an important example of a covalent bonded solid

Properties of covalent bond.

(i) Covalent bonds are very strong so that meterials having such bonds are quite hard.

(ii) Covalent compounds are poor conductor of electricity.

(iii) The covalent solids have high melting point.

Metallic bond. A metal behaves as if it is a regular array (arrangement) of positive ions immersed in a sea of uniformly distributed free electrons, the force that binds a metal atom to a number of electrons within its sphere of influence is called a **metallic bond**.

Properties of metallic solids.

Following are the properties of metallic solids.

(i) The metals acts as good conductors of electricity because the free electrons in metal act as charge carrier.

(ii) They act as good conductor of heat.

(iii) Metallic bords are non-directional. the metals can be readily deformed and also alloved with one another.

(iv) The metals present a lustrous appearance.

Vander Waal's bonds: The weak attractive forces between the atoms and molecules are called Vander Waal's forces. The bonds constituted by such forces are called Vander Waal's bonds (or molecular bonds).

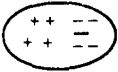
A molecule though electrically neutral does not have uniform distribution of positive and negative charges. The centre of mass of + ve charges does not coincide with the centre of mass of -ve charges. The molecule behaves as if + ve and - ve charges are separated by a certain distance. This is called an electric dipole. These dipoles attract each other and provide Vander Waal s bond.

For *Examples*, Benzene methane, Cl_2, I_2 etc.

Properties of Vander Waal's bonds.

(i) Molecular crystals are very soft and easily compressible because Vander waal's bonds are very-weak.

(ii) They have low melting and boiling points.



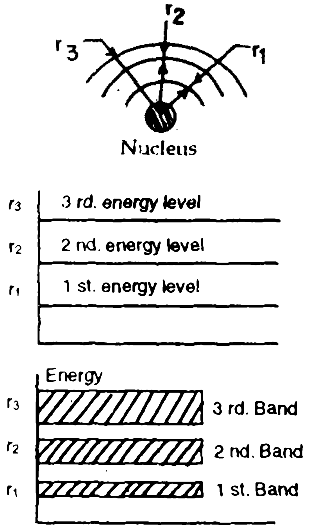
Distribution of Charges in molecule

Electric dipole

Fig.

(iii) They are poor conductors of electricity because of absence of any free electrons or ions.

Energy band: In case of a single isolated atom, the electrons in any orbit possess definite energy. An atom in a solid is greatly influenced by the closely-packed neighbouring atoms. Hence the electron in any orbit of such an atom can have a range of energies rather than a single energy which is known as energy band.



r_2
r_3
r_1
Nucleus
r_3
3 rd. energy level
r_2
2 nd. energy level
r_1
1 st. energy level
Energy
r_3
3 rd. Band
r_2
2 nd. Band
r_1
1 st. Band

Fig.

The range of energies possessed by an electron in a solid is known as energy band.

Bands in solids: The important bands in solids are

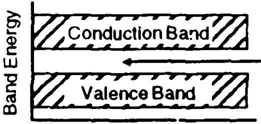


Fig.

(A) Valence band (B) Conduction band (C) Forbidden band.

(A) **Valence band.** Is the range of energies of band occupied by valence electrons. *Valence band has the electrons of highest energy.*

(B) **Conduction band** constitutes the range of energies possessed by constitutes *the range of energies possessed by conduction electrons. Conduction electrons* are the valence electrons which get detached from

the atom and become free electrons. These free electrons are responsible for the conduction of current in a conductor. Thus in conduction band:

(i) The conduction band is empty for insulator and partially filled for conductor.

(ii) All electrons are free electrons.

(iii) In conduction band the minimum energy of an electron is zero.

(C) **Forbidden energy gap.** Conduction known as band is separated from the valence band by a gap known us forbidden energy gap. No electrons of a solid can stay in the forbidden gap and when an electron from valence band absorbs energy equal to forbidden gap energy it jumps the forbidden gap and enters the conduction band.

Insulator. Valence band is full while the conduction band is empty. Further the energy gap between valence and con-

duction band is very large (15 el). Therefore a high electric field is applied to push the valence electrons to conduction band.

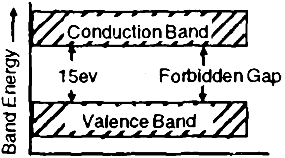


Fig.

Conductors: The unoccupied conduction band and filled valence band overlap each other as shown in figure. There is no energy gap and electrons can readily

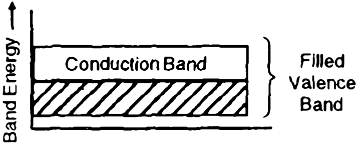


Fig.

pass into the conduction band when an electric field is applied, the electrons acquire energy to conduct.

Semi-conductor: The energy gap between the valence band and conduction band is comparatively small ($\approx 1eV$) Si and Ge are examples of semi-conductor. At absolute zero, all such materials are insulators. But at finite temperature it is possible for some electrons in the valance band to acquire enough thermal energy to jump into the conduction band leaving empty levels in the valence band called holes. These holes act-as charge carriers for the flow of current.

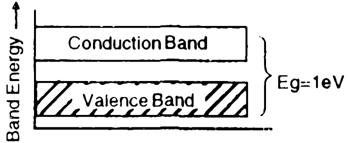


Fig.

Intrinsic semi-conductor: is one which is made of the semi-conductor meterial in its extremely pure form.

Extrinsic semi-conductor. Those intrinsic semiconductor to which some suitable impurity or doping agent or dopant has been added in extremely small amounts (about 1 part in 10^8) are known as extrinsic or impurity semi-conductor.

n-type semi-conductor. If an impurity atom of group V of the periodic table, like phosphorous, Arsenic is added to the pure semi-conductor (Ge or Si), then four of the five impurity electrons from covalent bonds by sharing one electron each of the four nearest Germanium atoms and fifth electron from each impurity atom is almost free to conduct electricity.

These additional electrons cannot be accomodated in the valence band, hence they occupy some discrete energy levels just near the bottom of the conduction band. The electrons are easily excited

from these levels into conduction band. The impurity so added is known as donor impurity

A semi-conductor dopped with pentavalent impurity is called **n-type semi-conductor**, which has an excess of negative charge carriers.

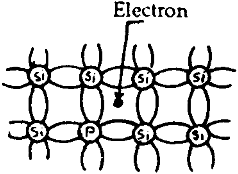


Fig.

P-type semi-conductor. If a trivalent impurity like boron, aluminium etc. is added in pure semi-conductor, the impurity atom can provide only three valence electrons for covalent bond formation. A gap is left in one of the covalent bond. This gap acts as a *hole* that tends to accept electrons.

Such impurity is known as acceptor impurity.

The crystal so formed is called *p-type semi-conductor* where *p* stands for positive charge carrier. Addition of each impurity atom makes the formation of a hole. The energy of these positive holes is slightly greater than the top of the filled valence band.

The electrons from valence band are excited by thermal energy to enter these holes. This results in the formation of new hole in valence band which is again filled by another electrcn producing another hole.

Thus a hole can move freely in the valence band.

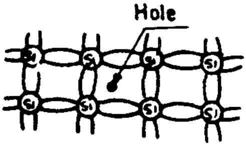


Fig.

Diode: It has only two electrodes and it is used for rectification of alternating current and for detection of radio-waves.

Dynamic resistance of diode: It is the ratio of a small change in volume, ΔV, to a small change in current ΔI. Thus

$$r_d = \frac{\Delta V}{\Delta I}$$

Principle of rectification: The alternating single voltage to be rectified is applied across the junction. When the signal is forward biased in the first half cycle, the alternating current is reverse biased and no current flows, In this way the signal gets rectified.

Transistor: It is a suitably prepared semi-conductor crystal of Germanium or Silicon with impurity of Antimony, Indium, Boron etc.

Triode: It consists of three electrodes (i.e. anode, filament and grid). The grid is inserted between the filament and the anode plate. The grid controls the flow of

electrons from the filament to the plate and hence the plate current. The addition of grid makes the value useful for magnifying oscillations. When the triode is used for magnifying current it is called an **amplifier**.

Amplification Factor: It is the ratio of change in plate voltage to cause a certain change in plate current to the change in grid voltage which can affect the same change in plate current. Thus

$$\mu = \frac{\Delta V_p}{\Delta V_g}$$

Plate Resistance: It is the ratio of change in plate voltage to the consequent change in plate current at constant grid voltage i.e.

$$\frac{\Delta V_p}{\Delta C_g} = R_p$$

Trans-conductance: It is the ratio of plate current to change in grid voltage at constant plate voltage

$$\frac{\Delta C_p}{\Delta V_g} = g_m$$

Triode valve can be used as an amplifier, detector etc.

STATE OF MATTER

Classification of the objects: All the objects in our surroundings are classified in three categories (1) solids, (2) liquids and (3) gases.

Identification of solids: An object is identified as a solid if it retains its shape indefinitely and generally resist change in its shape due to forces applied on it. A stone, table are some examples of the solids.

Few solids like paper, cloth change their shape easily and generally exhibit elasticity.

Deforming forces: When a body undergoes a change in its shape, length or volume under the influence of some external force, it is said to be deformed or strained and the force causing deformation is called the deforming force.

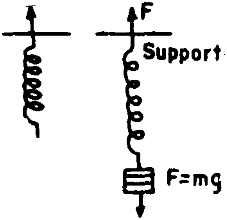


Fig.

Elasticity: Whenever a deforming force is applied on a body, it undergoes a change i.e., it gets deformed and when the deforming forces is removed, the body tends to regain it original shape and size due to the restoring force in it. *The property of body by virtue of which it regains its original shape and size when the deforming forces is withdrawn is known as elasticity.*

Perfectly elastic: A body which regains its original shape or size completely when the deforming force is with drawn, is said to be perfectly elastic.

Perfectly plastic: A body which retains its deformed shape and size when the deforming forces is withdrawn is said to be perfectly plastic.

Restoring force: A force which opposes the deforming force is called the restoring force. The force tends to bring the solid back to its original position and does so when deforming force is removed.

Elastic limit: The maximum stress (i.e. deforming force per unit area) the body can bear and yet return to its original shape and size when the deforming force is removed is known as elastic limit of the body.

Stress: When a deforming force is applied to a body the distance between the molecules changes. As a result of the molecules experience a mutual force of reaction which tends to restore its initial conditions.

This force or reaction is known as restoring force and the restoring force per unit area is called the stress.

$$\text{Stress} = \frac{\text{Restoring force}}{\text{Area}}$$

The S.I. unit of stress is Newton per meter squared, Nm^{-2}.

Strain: The change produced in a body by deforming force is called strain and is measured by change produced in some dimensions of the body divided by the total dimension.

Strains are of various kinds. In case of change in length the strain is called longitudinal strain and it is defined as *"The change in length per unit length." If L is the original length of a wire and l is the change in length on the application of force then."*

$$\text{Longitudinal strain} = \frac{l}{L}$$

Strain is a ratio of two similar physical quantities, it has no unit. It is just a number.

Young's modulus: Young's modulus is the ratio of stress to strain, when length of a solid changes.

$$Y = \frac{\text{Stress}}{\text{Strain}} = \frac{\text{Force/Area}}{1/L} = \frac{N/m_2}{m/m} = N/m_2$$

The S.I. unit of Young's modulus is N/m^2.

Hooke's law: Within the elastic limit the stress is directly proportional to the strain produced in it.

$$\therefore \text{ Stress} \propto \text{strain or } \frac{\text{stress}}{\text{strain}} = \textit{Constant.}$$

Free surface: The surface of a liquid that is in contact with the air above is known as the free surface.

Membrane: A very thin thickness of the liquid surface from the free surface towards the liquid side is called membrane.

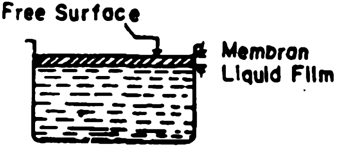


Fig.

Surface tension: is the property of a liquid due to which its surface behaves as stretched membrane.

Surface tension is measured as the force acting per unit length on the line supposed to be drawn along the surface of liquid. Its unit is Nm^{-2} or Jm^{-2}.

Capillary action: When a tube of very small bore is dipped into a liquid vertically, the level of liquid in it is either raised or lowered. This action of the capillary tubes is called capillary action.

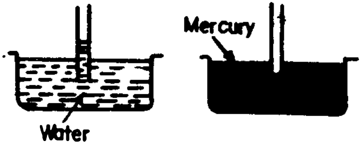


Fig.

Buoyant force: Whenever a body is immersed in liquid, an upward force acts on the body by the liquid.

This upward force is called buoyant force.

Buoyancy: The property by virtue of which a body immersed in a liquid experiences on upward thrust is called buoyancy.

Buoyant force depends upon.

(i) volume (V) of the solid body immersed in the liquid.

(ii) density of the liquid (p) in which the body is immersed, and

(iii) acceleration due to gravity (g)

Mathematically, Buoyant Force = $V.\rho.g.$

Buoyant force = weight of the liquid displaced by the body.

Centre of buoyancy: The point at which the buoyant force acts is known as the centre of buoyancy, and is defined as the centre of gravity of the displaced liquid.

Archimede's principle: When a body is

submerged wholly or partially in a liquid (or gas) it experiences an apparent loss in its weight which is equal to the weight of the liquid displaced by the body. If a body of volume v and density d is completely submerged in a liquid of density ρ then the apparent weight = $vdg - v\rho g$, where g is the acceleration due to gravity.

Density: of the substance of a body is the ratio of its mass and volume. It is also defined as: mass per unit volume of the substance. If the mass of a body is ***M*** and its volume be ***V***, then the density ρ of the substance of the body is given by

$$\rho = \frac{M}{V}$$

The unit of density is kgm^{-3} and the density of water at 4°C (277 k) is 1000 kgm^{-3}.

Relative density: of a substance is defined as the ratio of the density of that substance to the density of some standard reference substance.

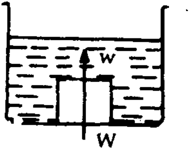
$$R.D. = \frac{\text{density of a substance}}{\text{density of a reference substance}}$$

As the relative density is a ratio of two similiar physical quantity, it has no unit.

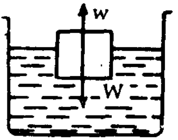
Principle of floatation of bodies: When a body is immersed in a liquid, it is acted upon by two forces (i) the weight W of a body acting vertically downwards through its C.G. and (ii) the upthrust ω exerted on the body by the liquid acting vertically upwards through the centre of buoyancy. Whether the body will sink or float, it all depends on the relative magnitudes of W and ω and three cases may arise viz $W > \omega$; $W = \omega$; and $W < \omega$.

(1) $W > \omega$ i.e., the weight of the body is more than the upthrust. In this case [(Figure (a)] the body will experience a net resultant downward force ($W - \omega$) and will therefore, sink to the bottom of the liquid. This is the reason why a piece of stone or iron sinks in water.

(2) $W = \omega$ i.e., the weight of the body is equal to the upthrust. In this case [Figure (b)] the net force acting on the body will be zero and the body will therefore float completely submerged in the liquid or remain hanging in whatever position it is left in the liquid.

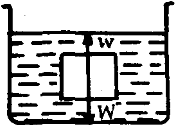


(a) $W > \omega$ *body sinks*



(b) $W = \omega$ *body floats*

(3) $W < \omega$ i.e., the weight of the body is less than upthrust. In this case [Figure (c)] the body will experience a net resultant upward force ($\omega - W$) and will therefore rise, and more of its portion emerges out more. It displaces less and less liquid. The upthrust, which is equal to the weight of liquid displaced, decreases. When the upthrust reduces to the extent that it becomes equal to the weight of the body, magnitude of the force acting on the body becomes equal to zero, equilibrium is reached and the body floats. Figure (*d*).



(c) $W < \omega$ body rises up till $W < \omega$

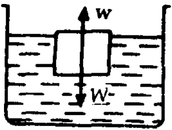


Fig. (d) $W < \omega$

The conditions for floatation of a body are: (i) The weight of the liquid displaced by the immersed part of the body must be equal to its own weight. (ii) The centre of gravity and the centre of buoyancy should be in the same vertical line.

Pressure: Force acting per unit area of the surface is called pressure. It is a scalar quantity. Its unit is Nm^{-2} or Pascal (symbol pa)

Pressure at a point: The normal force per unit area taken over a very small element of area surrounding the point.

Expression for the measure of pressure at any depth below the surface of a liquid is

$p = h\rho g$ where ρ is the liquid density filled in a vessel and h is the depth below the liquid surface and g is the acceleration due to gravity.

·***Pascal's law:*** Whenever a pressure is applied from outside on an enclosed liquid at rest the pressure is increased at every point in the liquid by an amount equal to the externally applied pressure. Hence it is the pressure and not the force which is transmitted throughout the liquid.

Atmospheric pressure: The pressure exerted by the atmosphere at a place is known as the atmospheric pressure at that place. The unit of atmospheric pressure is Nm^{-2} (Newton per meter squared).

Siphon: Siphon is a simple method to transfer a liquid from one vessel into another. It works on the principle that liquids flow from higher pressure to the lower pressure. The vessel from which the liquid is to be transferred is kept at a higher place. A long rubber tube is filled

with the liquid and one end is dipped in the vessel from which the liquid is to be transferred, and the and the other end is placed in the other vessel. The liquid starts flowing from the vessel kept at higher place to another.

Barometer: is a device to measure the atmospheric pressure.

Stream line motion: The liquid whose molecules flow smoothly and the velocity of all molecules at a particular cross-section is same, is said to have stream line motion.

Turbulent motion: The liquid whose molecules flow violently and the velocity of different molecules along a given cross-section at a given instant is different is said to have turbulent motion.

Viscosity: The property of a liquid by virtue of which it opposes the relative motion between its different layers is known as **viscosity.**

Principle of continuity: If an compressible and non-viscous liquid flows through a

tube of non-uniform cross section, the product of velocity of liquid and the area of cross-section is a constant.

For continuous flow $A_1 v_1 = A_2 v_2$

or $$Av = \text{constant}$$

or $$v \propto \frac{1}{A}$$

The velocity of liquid is more where area is smaller.

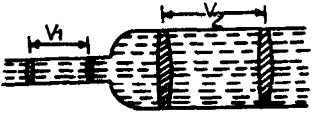


Fig.

Bernoulli's principle: "For an incompressible liquid flowing along a tube of varying cross-section the pressure and velocity are inversely proportion to each other" *i.e.*, when the speed of the liquid in a tube or

pipeline increases, the pressure decreases and conversely when the speed of the liquid decreases the pressure increase.

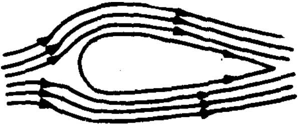


Fig.

Torricelli's Theorem. The liquid placed in a container to a height having a hole at the bottom then velocity of efflux $= \sqrt{2gh}$ it is independent of liquid.

Structure of atom: An atom consists of a central positively charged region called nucleus. Negatively charged electrons revolve around it. The nucleus consists of protons and neutrons. A proton carries a charge (positive) of $1{\cdot}6 \times 10^{-19}$ C. A neutron does not possess any charge. Mass of proton is roughly equal to that of

the neutron i.e. $1{\cdot}67 \times 10^{-27}$ kg. The change on an electron is $1{\cdot}6 \times 10^{-19}$ C and its mass is $9{\cdot}1 \times 10^{-31}$ kg which is $\frac{1}{1840}$ times that of a proton or a neutron. Thus the whole mass of an atom is practically concentrated in its nucleus. An atom is electrically neutral. So the number of protons inside the nucleus is equal to the number of electrons revolving around it.

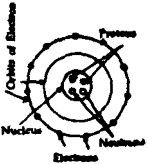


Fig.

Comparison of atomic model with solar system:

Similarities (i) Planets revolve around the sun. Electrons also revolve around the nucleus.

(ii) Most of our solar system is an empty space. Atom is also an almost empty space.

Dissimilarities (i) Gravitation force binds the planets to the sun $\left(F=\frac{G.M.m}{r^2}\right)$ coulomb's force binds the electron to the nucleus. $\left(F=\frac{kq1q2}{r^2}\right)$

(ii) A planet can revolve around the sun in any orbit. It can have any energy and the energy can very continuously. In an atom, the electron can revolve only in certain fixed orbits. They can have only certain discrete (fixed) energy values.

(i) ***Atomic number:*** (ii) mass number: (i) The number of protons (or electrons) in

an atom is called its atomic number (Z). (ii) the total number of particles inside the nucleus (both the protons and neutrons) is called mass number (*A*).

Isotopes: Atoms with same atomic number but different mass number are known as isotopes. The chemical properties of an atom depend upon it atomic number, the isotopes of an element are chemically in distinguishable.

Emission of lights by atoms: An electron jumps from a lower energy state (lower orbit) to a higher energy state (higher orbit) by absorbing energy in the form of quantum of light. Similarly when an electron jumps from a higher energy state to a lower energy state (lower orbit) it releases energy in the form of a quantum (packet of energy) of light.

(i) $1^{0}A$ (ii) 1 fm

(i) $1^{0}A = 10^{-10}m$ (ii) $1\ fm = 10^{-15}m$.

Deuterium: is the heavier isotope of hydrogen. It is written as ${}^{2}_{1}H$ or ${}^{2}D$. It has

a proton and a neutron inside its nucleus. The nucleus has only one electron revolving round it.

Heavy water: Water molecule formed by the heavier isotope of Hydrogen (namely deuterium) with oxygen is alled heavy water and is chemically written as D_2O.

Three Isotopes of uranium: Natural uranium consists of three isotopes ${}^{238}_{892}U$, ${}^{235}_{92}U$ and ${}^{234}_{92}U$. The heaviest isotope ${}^{238}_{92}U$ is the most abundant in nature, being 99·282% of deposits and ${}^{235}_{92}U$ is 0·712% while ${}^{234}_{92}U$ occurs in traces (less than 0·006%) only.

Radioactivity: Nuclei which emit radiations e.g., alpha particles, beta particles or gamma rays are called radioactive nuclei.

This phenomenon is called radioactivity. This phenomena was discovered by Bacquerel. This phenomenon is found among heavy nuclei only.

Properties of α rays:

(i) Mass of an particle is 4 times the mass of a proton or hydrogen nucleus and is equal to that of helium nucleus.

(ii) They are deflected by electric or magnetic field.

(iii) Their penetration power is $\frac{1}{10,000}$ of the γ-rays and $\frac{1}{100}$ that of β-rays

(iv) They cause florescence.

(v) They possess large velocities, therefore large kinetic energy.

(vi) They are scattered and they pass through metal sheets.

(vii) They are used for producing artificial disintegration of the nuclei.

Properties of β-rays:

(i) The mass of a β partical is equal to the mass of an electron.

(ii) The charge of a β-particle is also equal to the charge on an electron.

(iii) Their ionising power comparatively small being $\frac{1}{100}$ times that due to α-particles and 100 times that due to γ-rays.

(iv) They are deflected by electric and magnetic fields.

(v) They possess less kinetic energy because their mass is less

(vi) They are 100 times more penetrating than α-particles but $\frac{1}{100}$ times that due to γ-rays.

(vii) They produce flourescence, they affect a photographic plate.

(viii) Their velocities range between 30 to 90% of the velocity of light.

(ix) When they fall upon heavy metals, they produce X-rays.

Properties of γ-rays:

(i) They are electromagnetic waves and have wave length of the order of

10^{-12} m.

(ii) If they fall upon a substance they emit β-particles.

(iii) They have very small ionising power, $\frac{1}{100}$ times that due to β-particles.

(iv) They travel with velocity of light i.e, $3 \times 10^8 ms^{-1}$

(v) They possess no charge and are therefore unaffected by electric or magnetic field.

(vi) They have large penetrating power 100 times that of β-particles and 10000 times that of α-particle.

(vii) Intense γ rays produce flourescence.

(viii) They produce photoelectric effect.

(ix) They are diffracted by crystals.

Positron: is a positively charged particles which has same mass as that of a β-particle (i.e, electron) but an equal positive charge. Wherever a proton converts itself into neutron, a position is emitted.

Nuclear reaction: The process of converting one element into another by artificial means is called a nuclear reaction or transmutation.

When an α-particle interacts with the nucleus of a nitrogen atom oxygen is produced. This reaction can be written as

$${}_{2}^{4}He + {}_{7}^{14}N \rightarrow {}_{8}^{17}O + {}_{1}^{1}H$$

A nuclear reaction can be carried out by using α-particles protons, deutrons, tritones, neutrons etc.

Fission: If ${}_{92}^{235}U$ is bombarded by a low energy neutron, it splits up into two nearly equal fragments and a large amount of energy is released. The phenomenon according to which a heavy enucleus splits up into two nearly equal fragments with the release of a large amount of energy is called fission. 1 gm of ${}_{92}^{235}U$ when undergoes fission produces about 10^7 Joule of energy which is equivalent to burning about 4 tones of coal.

Chain reaction: A reaction which

produces the particles which initiated the reaction is called a chain reaction.

When $^{235}_{92}U$ is bombarded by a low energy neutron it splits up into two nearly equal fragments and three neutrons are also produced. These additional neutrons cause further the fission of more $^{235}_{92}U$ atoms and so on. In an uncontrolled chain reaction, a tremendous amount of energy is evolved which can cause explosion.

Fusion: It is a phenomenon, according to which two or more small nuclei combine together to form a single heavy nucleus. During this process, a large, amount of energy is released.

(i) ${}_1H^2 + {}_1H^2 \rightarrow {}_2H^2_2$

(ii) ${}_1H^1 + {}_1H^1 + {}_1H^1 \rightarrow {}_2H^4_2 + 2{}_1\beta^0$

(positron)

The source of energy is sun and other star is a fusion process.

Radio isotopes. Artificially produced

isotopes which exhibit radioactivity are known radioactive isotopes or radio isotopes. A radio isotope of any element chemically behaves exactly like other isotopes (i.e.,) normal of that element. But the radio isotopes emits radiations α, β, γ-rays, so one can follow its cause during the reaction by detecting the radiations emitted. On this principle radio isotopes find use in various field like medicine, agriculture, industry etc.

LIQUIDS

Intermolecular forces and states of matter: Every matter consists of extra-ordinariiy small particles known as molecules. Molecules of a body have inter molecular attraction among themselves. At ordinary temperatures, however, some sort of thermal motion is also associated with molecules. Thus molecules of a body are under the combined effect of these and two and their relative strength give rise to three states of matter i.e., solid liquid and gas.

Solids: The force of inter-molecular attraction is very strong and weak thermal agitation is unable to break the molecules away and Molecules are allowed to vibrate to and fro about their mean posi-

tions. Thus it is clear that solid bodies have a definite volume as well as definite shape of their own.

Gases: The intermolecular forces of attraction is so weak that random thermal motion can very easily overcome them. Thus molecules are almost free to move about any where in space available. Thus gas has no size and shape of its own.

Liquids: A liquid occupies a position which is some what in between the two extremes *i.e.*, solid and gas. In case of liquid although the molecules are to move about any where in the liquid still they are held together due to comparable attractive forces.

The molecules in a liquid are neither forced to sty permanently in an equilibrium position nor free to leave the company of other molecules. A liquid has fixed volume but has no shape of its own.

Force of cohesion: The force of attraction between the molecules of the same sub-

stance is called the force of cohesion or the cohesive force.

Force of adhesion: The force of attraction between the molecules of two different substances is called the force of adhesion or the adhesive force.

Surface tension: It is the property of liquids by virtue of which their free surfaces at rest behave like elastic stretched membranes with a tendency to contract so as to occupy minimum surface area.

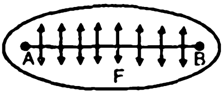


Fig.

The magnitude of the force acting per unit length on either side of an imaginary line drawn in the free surface of a liquid is called surface tension.

∴ Surface Tension,

$$\sigma = \frac{\text{force on either side of the imaginary line 'F'}}{\text{length of the line 'l'}}$$

Unit of surface tension is Nm^{-1}. Its dimensions are $[MT^{-2}]$.

Surface energy: is the potential energy stored in the surface film of a liquid by virtue of it special position.

Relation between surface tension and surface energy: Surface energy = Surface tension × area.

Surface tension of liquid is equal to the amount of mechanical energy spent in increasing the area of its free surface by unity.

Angle of contact: The angle of contact is the angle θ measured in degrees, which

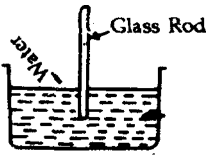


Fig.

the tangent to curved liquid surface at the point of contact, makes with the solid inside the

Excess of pressure inside a liquid drop: is given by the expression,

$$p = \frac{2\sigma}{R}$$

where σ is the surface tension and R the radius of the liquid drop.

Excess pressure inside σ soap bubble: is given by the expression,

$$p = \frac{4\sigma}{R}$$

Capillarity: The phenomenon of rise or fall of a liquid in a capillary tube in com-

Fig.

parison to surroundings is called capillarity.

Expression for the ascent of a liquid in a capillary tube: The rise of the liquid column (h) is given by,

$$h = \frac{2\sigma\cos\theta}{r\rho g} - \frac{r}{3}$$

where r is the radius of the tube, σ is the surface tension, ρ is the density and angle of contact of the given liquid with glass is θ

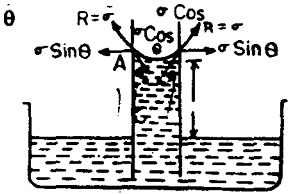


Fig.

Fluid: is that state of a substance which has the ability to flow. A fluid is of two kinds:

(i) liquid has a definite volume but has no shape of its own

(ii) gas has neither any fixed volume nor has any definite shape of its own.

Steady flow (stream line flow): When a liquid is allowed to flow such that each particle of the liquid passing a point travels along the same path with same speed as the preceding particles, which have passed the same point, the flow is said to be steady flow.

Turbulent flow: In a turbulent flow velocity of liquid particles leaving a fixed point is not constant, but changes continuously.

Equation of continuity of ideal liquid: is given by $a_1 v_1 = a_2 v_2$ where a_1, a_2 are two transverse section of the tube and v_1, v_2 be the respectively the velocities. From above relation it is clear that the velocity of flow of liquid is inversely propotional to the area cross-section.

Velocity is small at those points where area of cross-section of the tube is large and *vice-versa*.

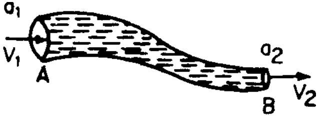


Fig.

Bernoulli principle: Bernoulli's principle states if a small amount of an incompressible, non-viscous liquid flows from one point to another, its total energy remains the same throughout the displacement.

Bernoulli's equation: According to Bernoulli's principle of a liquid in motion sum of it pressure energy + gravitational potential energy + kinetic energy is constant.

∴ For flow of unit mass of liquid, we have

$$\frac{P}{\rho} + hg + \frac{1}{2}v^2 = \text{constant.}$$

Critical velocity: A velocity of flow of a liquid at which the stream line flow changes into turbulent flow is called critical velocity.

Reynold's number: A flow of a viscous fluid through a pipe is determined by a combination of four factors called Reynold number N_R.

$$N_R = \frac{\rho . v . D}{\eta}$$

where ρ is the density of the liquid; v its average speed; D the diameter of the pipe and η the coefficient of viscosity.

Viscosity (***internal friction***)***:*** It is a property by virte of which a liquid opposes the relative motion between the different layers.

Coefficient of viscosity of a liquid is the tangential opposing force acting on unit surface area of the liquid layer moving in a region of unit velocity gradient normal to the layer, *i.e.*, $F = -\eta$

S.I. unit of viscosity is kg m^{-1} s^{-1}.

Poiseuille's formula: The relation $V = \frac{\pi p r^4}{8\eta l}$ is known as Poiseuille's formula where V is the volume of liquid flowing

out per second, p is the pressure difference across the two ends of the tube, r is the radius of the tube, l is the length of the tube, η is the vicosity of the liquid.

Terminal velocity: When a body falls through a fluid, it attains a certain velocity after which the retarding viscous force just becomes equal to the effective weight of the body and the body thereafter begins to fall with a constant velocity

This maximum velocity attained by a body while falling through a viscous medium is terminal velocity. (*i.e.*)

$$V = \frac{2r^2(\rho - \sigma)g}{9\eta}$$

Unit is ms^{-1} and dimensions is $[M^0L^1T^{-1}]$.

Stoke's law: Stoke's law states that the backward viscous force acting on a small spherical body of radius 'r' moving with a uniform velocity 'V' through a fluid medium of coefficient of viscosity 'η' is given by

$$F = 6\pi\eta rV.$$

THE KINETIC THEORY OF GASES

Fundamental assumptions of kinetic theory of gases: Are made regarding the model of the gas.

(i) The molecules of a gas consists of hard, perfectly elastic spheres of very small size so that the volume which they occupy is a negligible fraction of the total volume of the gas.

(ii) The molecules are in a state of continuous random motion, moving in all possible directions with different velocities.

(iii) Collisions are almost instantaneous *i.e.*, the time for which collision lasts is very small as compared with the time

elapsed between two successive collisions.

(iv) Between two consecutive collisions, a molecule travels in a straight line with a uniform velocity. The average distance through which a molecule moves freely between two successive encounters is called the *mean free path.*

(v) Since the distance between the molecules of a gas is large as compared to that in case of a solid or a liquid, the force of attraction (cohesion) between the gas molecules is supposed to be negligible.

(vi) The moleculor collision do not disturb the average density of the gas.

Kinetic theory and gas pressure: The pressure of a gas is the result of continuous bombardment of the gas molecules against the walls of the container and is equal to the total momentum

imparted per second per unit area of the walls of the container by the bombarding molecules.

Expression for gas pressure on the basis of kinetic theory: $\rho = \frac{1}{3}\frac{mn}{V}C^2$

where n is the number of gas molecules, m is the mass of each molecule and c is called *root mean square velocity* or $\rho = \frac{1}{3}\frac{m}{V}C^2$ where $(m \times n)$ denotes the total mass of gas say M or $P = \frac{1}{3}\rho C^2$

where ρ is the density of a gas

or $\quad P = \frac{1}{3}\rho c^2 = \frac{2}{5} \times \frac{1}{2}\rho c^2$ or $\rho = \frac{2}{3}E$

where $E\left(= \frac{1}{2}\rho c^2\right)$ stands for the kinetic energy per unit volume of the gas.

Derivation of the following laws: Following laws can be derived from the kinetic theory of gases.

(i) Boyle's law *i.e*, $PV =$ constt.

(ii) Charles law i.e. $P \propto T$

(iii) Avogadro's law *i.e.*, $n_1 = n_2$

(iv) Grahm's law of diffusion i.e.

$$\frac{r_1}{r_2} = \frac{\sqrt{\rho 2}}{\rho 1}$$

(v) Dalton's law of partial pressure *i.e.*,

$P = p1 + p2 + p3 +$

Degrees of freedom: The total number of co-ordinates or independent quantities which must be known in order to describe completely the position of an object or the state of a system is known as the degrees of freedom of the object or system.

Degree of freedom of monoatomic gas: Molecule of a monoatomic gas like neon helium argon etc. consists of only one atom. and is capable of only translatory motion in free space. Hence it has **three degree of freedom permolecule**.

Degrees of freedom of diatomic gas: Each molecule of diatomic gas e.g. H_2,

Cl_2, N_2 etc. consists of two atoms so diatomic molecule has

(i) three degrees of freedom if it possesses translatory motion only.

(ii) five degrees of freedom if it possesses translatory and rotational motion only and

(iii) six degrees of freedom if it possesses translatory, rotational and vibrational motions.

Law of equipartition of energy: Defines that in any dynamical system in thermal equilibrium, the total energy is distribute equally amongst all the degrees of freedom and the average energy per degree of freedom per molecule $= \frac{1}{2}kT$.

Kinetic Energy of a Molecule

(i) *Monoatomic molecule* $= 3 \times \frac{1}{2}kT = \frac{3}{2}kT$

(ii) *Diatomic molecule* $= 5 \times \frac{1}{2}kT = \frac{5}{2}kT$.

Specific heat of a gas: The specific heat

of a matter is defined as the amount of heat energy required to raise the temperature of unit mass of it through unit temperature change.

Since heat is in form of energy, the S.I. unit of heat is joule.

The S.I. unit of specific heat is J kg^{-1} K^{-1}.

Molar specific heats of a gas: Two specific heats of a gas are

(i) ***Specific heat at constant volume*** (C_v) is defined as the amount of heat energy required to raise the temperature of 1 *g* mole of the gas through 1 *k* when its volume is kept constant.

(ii) ***Specific heat at constant pressure*** (C_v): is defined as the amount of heat energy required to raise the temperature of 1 mole of the gas through 1 *k* when its pressure is kept constant.

Both C_v and C_v are measured in J $mole^{-1}$ K^{-1} in S.I. They are called *molar* specific heats.

C_v is greater than C_v: The specific heat at

constant pressure is greater than specific heat at constant volume by the thermal equivalent of the work done by the confined gas in expanding against external pressure.

Relation between C_p C_v, R and J:

$$C_v - C_v = \frac{R}{J} \text{ cal mole}^{-1}\,\text{k}^{-1}.$$

PHYSICS OF THE ATOM

Cathode Rays- Cathode rays are nothing but a stream of electrons, shot out at a high speed from the cathode of discharge tube at low pressure. Cathode rays are produced when the two electrodes of a discharge tube are connected to a source of high voltage such as an induction coil and the pressure in the tube is less than 0.01 mm of mercury.

Properties of cathode rays:

1. Cathode rays are emitted normally from the surface of the cathode
2. They travel in straight lines and cast shadows of obstacles in their path.
3. They produce fluorescence on cer-

tain substance *e.g.*, zinc sulphide etc.

4. They effect the photographic plate.
5. They possess kinetic energy and exert mechanical pressure on objects placed in their path.
6. Cathode rays produce heat when they strike an obstacle.
7. They travel with a velocity of about $\frac{1}{10}$th the velocity of the light.
8. They are deflected by electric field towards the -ve charged plate. This proves that cathode rays are negatively charged particles (electrons).
9. When cathode rays strike against a target of a heavy atomic weight *i.e.*, tungsten etc. they produce X-rays.
10. They ionise the gas through which they pass.

Positive or canal rays: As the cathode particles (electrons) in the discharge tube from the cathode move towards the anode, they frequently colloid with

neutral atoms of the gas and causes ionisation of them. As the gas during its ionisation loses one or more electrons, it has a negative charge on it. This + vely charged atom or +ve ions is repelled by the anode and is acceleratea towards the perforated cathode. A few of the + ions find their way through the holes in the cathode and strike the fluorescent screen to produce fluorescences.

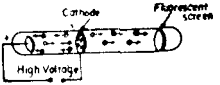


Fig.

Properties of positive rays:

Positive rays travel in a straight line. Positive rays affect photographic plates. Velocity of + ve rays is less than that of cathode rays since - ve ions are much

more heavier than the electrons. Positive rays are deflected by electric and magnetic fields but their direction of deflection will be opposite to the direction in which the cathode rays are deflected. Specific charge of + ve rays is much smaller than the specific charge $\left(\frac{e}{m}\right)$ of cathode rays. Positive rays have penetrating power, they can pass through thin sheets of metal *i.e.* Al.

Millikan's oil drop experiment: This method is based upon the rate of motion of a small oil drop under free fall due to gravity and under the application of suitable electric field.

By adjusting the electric field suitably, a given oil drop can be made to move up or down or even kept balanced in the field of view for sufficiently long time and a series of observations can be seen.

$$q = dq = \frac{4\pi(\rho - \sigma)g}{3E} \cdot \left(\frac{9\eta v_1}{2(\rho - \sigma)g}\right)^{3/2}$$

$$\therefore \quad a = \sqrt{\frac{9\eta v_1}{2(\rho - \sigma)g}}$$

where a is the radius of oil drop, ρ = density of oil, σ = density of air, g = acceleration due to gravity, η = coefficient of viscosity of air, E = strength of electric field. v_1 = constant terminal velocity.

Millikan experiment gave the value of

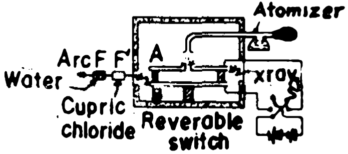


Fig.

charge on electron as 1.59×10^{-19} coulomb.

Thomson's atomic model. Sir J.J.Thomson discovered that atom is spherical in shape.

Every atom has negatively charged par-

ticles called electrons and that atom has positive charge equal and opposite to that of electrons, the electrons being embedded in the positive charge.

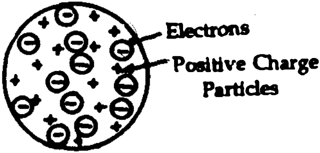


Fig.

Thomson atomic model is also sometimes called Thomson's plumpudding atomic model. But there are certain drawbacks which are

(i) Observation made by Thomson that number of electrons in an atom is equal to its atomic weight was wrong.

(ii) Assumption by Thomson that there was a uniform distribution of positive charge in a sphere of atomic dimension was wrong.

(iii) Thomson model could not explain the number and distribution of electrons in an atom.

(iv) Thomson model could not explain large angle scattering of α -particles by atom as proved by Rutherford.

Rutherford's atomic model: Rutherford proved that atom has all the positive charge concentrated in a very small central region called the nucleus and that nucleus is surrounded by negatively charged particles called electrons revolving in orbits.

He observed that the force of attraction between electrons and nucleus was counter balanced by the centrifugal force acting on the revolving electron. This provided stability to the atom (see fig below). The force of attraction (F_1) between the electron and nucleus is given by

$$F_1 = \frac{Ze^2}{4\pi\varepsilon_0 r^2}$$

where, e = Charge on electron
Z = Total number of electrons
r = Radius of orbit in which electron is revolving
V = Velocity of electron
m = Mass of electron
ε_0 = Permittivity of free space.

The centrifugal force (F_2) acting outwardly on the ele... is given by

$$F_2 = \frac{mV^2}{r}$$

Now, $F_1 = F_2$

$$\frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{mV^2}{r}.$$

Rutherford proved that the large scattering of particles due to the presence of heavily charged positive nucleus. He bombarded a thin aluminium foil with α-particles and found that α-particles passing close to nucleus got deflected through greater angles.

This was due to very strong repulsion α

-particles suffered because of high concentrated positive charge.

(i) It could not explain the distribution of electrons outside the nucleus.

(ii) It could not explain the stability of atom as whole. According to fundamental law of electric magnetic theory an accelerated charge must emit electro-magnetic energy or radiation continuously. The electrons therefore moving round the nucleus will continuously lose energy and finally they will spiral towards

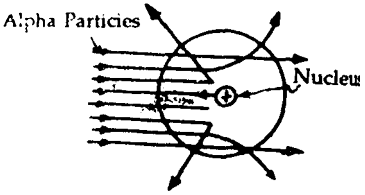


Fig.

nucleous and fall into it when all the rotational energy got spent on radiations.

Bohr's atomic model: Neil Bohr observed that basic features of Rutherford's atomic model namely presence of nucleus and revolving electrons were correct but that the electrons revolved round the nucleus in certain allowed circular orbits and that the electrons did not radiate and therefore its energy remained constant.

However, the electron could jump from outer stationary orbit to inner orbit and while doing so emits radiation equal to the difference in energies corresponding to the two orbits.

The frequency (f) of the radiations emitted is given by

$$E_1 - E_2 = h.f$$

where E_1 and E_2 energy of two orbits and h is Planck's constant.

The frequency (f) is also given by the relation.

$$f = \frac{mZ^2 e^4}{8\varepsilon_2 h^3}\left[\frac{1}{n1^2} - \frac{1}{n2^2}\right]$$

Where n_1 = inner orbit

n_2 = outer orbit

(the electron jumps from outer orbit (n_2) to inner orbit (n_1)) m = mass of electron, Z = number of electrons, e = charge on electron, h = Plank's constant, ε_0 = permittivity of free space $= 8.85 \times 10^{-12}$ Farad/metre.

Bohr proved that the angular momentum (moment of momentum) of an electron is an integral multiple of $\frac{h}{2\pi}$

Angular momentum = mvr

$$\text{mvr} = \frac{nh}{2\pi}$$

where m = mass of electron,

r = radius of stationary orbit

v = velocity of electron,

h = Planck's constant,

$n = 1, 2, 3$ ..... a whole number integer.

Atomic Spectrum: A group of wavelength of radiations are emitted by an atom when its electron move from higher orbits to lower orbits. This group of wavelengths is known as atomic spectrum.

Normal and excited atom: Atom is said to be in normal or ground state when all the electrons in an atom have the lowest possible energy whereas an atom is called excited atom when one or more electrons possess energy more than in the ground state.

Energy level diagram of hydrogen atom: According to the theory of Bohr the energy (E_n) an electron revolving in the 8th orbit is given by

$$E_n = \frac{mZ^2e^4}{8\varepsilon_0^2 n^2 h^2}$$

The energy of an electron of hydrogen atom is calculated as follows :-

$$E_n = -\frac{mZ^2e^4}{8\varepsilon_0^2 n^2 h^2}, \ Z = 1 \text{ for hydrogen atom}$$

$$E_n = \frac{me^4}{8\varepsilon_0^2 n^2 h^2}$$

$$= -\frac{(9.1 \times 10^{-31})(1.6 \times 10^{19})^4}{8(8.854 \times 10^{12})^2 n^2 (6.62 \times 10^{-34})^2}$$

$$= -\frac{2.17 \times 10^{-19}}{n^2} \text{ Joules}$$

$$= -\frac{2.17 \times 10^{-19}}{(1.6 \times 10^{-19})n^2} ?$$

$$eV = -\frac{13.6 eV}{n^2}$$

where eV = Electron volt and 1 eV

$= 1.6 \times 10^{-19}$ Joules

when $n = 1$, $E_1 = -13.6\ eV$

$n = 2$, $E_2 = -3.4\ eV$

$n = 3$, $E_3 = -1.51\ eV$

$n = \infty$ $E_\infty = 0\ eV$

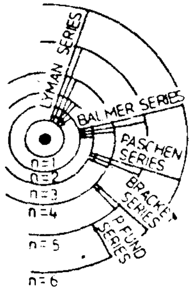


Fig.

Hydrogen series: consists of group of radiations emitted by a hydrogen atom whose wave lengths could be represented by a simple formula—as

Balmer series: In Balmer series the wavelength of group of radiations emitted by a hydrogen atom was given by

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

where n is an integer whose value is greater than 2.

Lyman series: In lyman series the wavelength (λ) of group of radiations emitted by a hydrogen atom was given by

$$\frac{1}{\lambda} = R\left(\frac{1}{l^2} - \frac{1}{n^2}\right)$$

where R = Rydberg's constant

n is an integer whose value is greater than 1.

Bracket series: In this series the wavelength was given by

$$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$$

where n is an integer whose value is greater than 4.

Paschen series: In this series the wavelength of group of radiations emitted by hydrogen atom was given by

$$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$$

where n is an integer whose value is more than 3.

P-Fund series: In this series the wavelength of group of radiation emitted by a hydrogen atom was given by

$$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n^2}\right)$$

where n is an integer whose value is greater than 5.

Vector atomic model: is the latest atomic model of today and it considers the principal quantised terms as vectors.

Concepts of vector model: The two main concept of vector atomic model are as follows: (A) Spinning of electrons (B) Spatial electron motion.

(A) ***Spinning of electrons:*** Sommerfeld's atomic model could not explain the presence of several lines in the spectrum of complex atoms like argon etc. In 1925 Geroge Uhlenbeck proposed that

electrons spin about their own axis and these electrons have two types of motion namely orbital motion and spin motion. Due to the electron spin many additional energy states are possible in an atom which explains the super fine structure.

(B) ***Spatial electron motion:*** It is found that when an electron is placed in an electric or magnetic field several new lines are created in addition to super fine structure. This is due to the fact that on the application of electric or magnetic field additional planes of electron orbits are created and the orbiting of electrons round the nucleus in these different planes is responsible for the presence of additional lines in the spectrum.

Quantum Numbers: They completely specify the state of an electron within an atom. There are four quantum numbers.

Principal or Total Quantum Number (n). This quantum number is identical with that used in Bohr Sommerfeld theory. It can have only non zero positive integral

values

i.e., $n = 1, 2, 3, \ldots\ldots\infty$

In quantises the principal orbits.

It controls the size of electron orbits and also controls the electron energy. The energy levels or shells of electrons are denoted by means of capital letters as indicated.

Total Quantum No.	Atomic shell
1	*K*
2	*L*
3	*M*
4	*N*
5	*O*
6	*P*
7	*Q*

Azimuthal Quantum Number: (i). It states that the shape of electron orbits as well as the orbital angular momentum of the electron. The orbital angular momentum

(pl) of an electron is given by $pl = \sqrt{l(l+1)}\,\frac{h}{2\pi}$ where h is Planck's constant. It can have values of 0,1,2,3,...(n–1). Each value refers to an energy sub-shell. The second principal sub-shell or L shell will have two sub-shells. With two values of azimuthal quantum number (l), they are designated as follow :

S-sub-shell when l = O, P-sub-shell when l = 1.

The relation between l, n, a and b is as follows:

$\frac{b}{a} = \frac{l+k}{n}$ where a and b represents the lengths of semi-major and semi-minor axis of the ellipse.

Magnetic orbital quantum number: (ml. It is due to the quantization of the direction of orbital angular momentum and determines the exact orientation of the electron orbit in space. It can have values from l to - l at unity intervals *i.e.*, l, l 1, l-2,

......1.0-1.....(l-1), -l i.e., all integral values between O to $\pm$ 1.

Magnetic spin quantum number: (ms). This number is due to the orientation of the spin angular momentum and determines the spin orientation of the electrons about their own axis. It can have only two values $\frac{1}{2}$ and $-\frac{1}{2}$

Pauli's exclusion principle: States that no two electrons in an atom can exist in an identical values for four quantum numbers. This principle is used to determine the maximum number of electrons in main shell and its orbitals.

Electronic configuration: is the distributions of electrons in orbits and orbitals around the nucleus of an atom.

X-rays: When fast moving electrons (cathode rays) fall on a target of high atomic weight, *X*-rays are produced. Only 1% of energy of the incident electrons appears as *X*-rays, the remaining appears as heat.

X-rays are electromagnetic radiations of very short wave lengths varying about

0.02 A.u to 100 A.u (1 A.u = 10^{-10} m).

Production of X-rays: The modem type of X-ray tube consists of highly evacuated hard glass bulb containing a cathode and anode. The electrons are emitted by the process of thermionic emission from the cathode.

Origin of characteristic X-rays: If the electron of orbit K (inner most orbit) is knocked out by fastmoving electron and the knocked out electron then it is replaced by jumping of an electron from the higher orbits giving rise to K series of the lines of spectrum. The jumping of the electrons from $n = 2, 3, 4$ etc to $n = 1$ gives rise to X-ray called K_α, K_β, K_γ, etc. radiations.

Origin of continuous X-rays: The origin of the continuous X-ray spectrum emitted by the target is the slowing down of high speed electrons as they pass close to the nuclei of atoms inside the target of the

X-rays.

As high speed electron passes through the atom, it is attracted by the +ve charge of the nucleus and so it is deflected in its path and emits a photon ($h\nu$) of frequency ν. This frequency ν lies in the *X*-ray region.

Mosley law: showed that the frequency of these radiations is directly proportional to the square of the atomic number, given by

$$\nu = RZ^2$$

where ν is the frequency, R is a constant and Z is the atomic number. The graph between $\sqrt{\nu}$ and Z is a straight line.

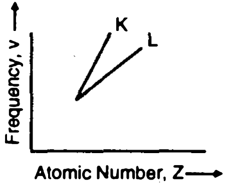


Fig.

Bragg's law: Proved that for a given X-ray diffraction by regularity spaced atomic centres in a set of parallel planes with interplaner spacing d, and using homogeneous radiation of wavelength λ, reinforcement would occur only at those angles which satisfy the relation

$$n\lambda = 2d \sin \theta$$

where n is called the order and is an integer, and θ being the glancing angle or angle of incidence, or angle of reflection of diffacted beam.

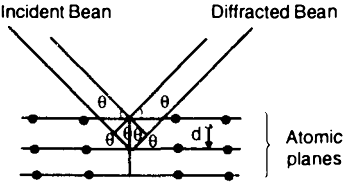


Fig.

Bragg's X-ray spectrometer: In this apparatus X-rays are first narrowed down to a fine line by means of two slits A and B. This fine line of X-ray is incident on a crystal C at an angle θ. Then the reflected X-rays pass through a detector D. Now, the direction of incident X-ray and position of Director is kept fixed then the crystal mounted on a turn table is rotated about its central axis and angle θ is recorded. The relation between d (inter planar spacing), λ (the wave length of X-rays) and θ (the angle of the reflected X-rays) is given by Bragg's law as

$$N \sin \theta = n\lambda$$

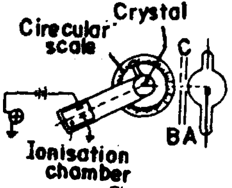


Fig.

Where n is the order of spectrum. Thus knowing the value of θ and order of spectrum *n* the wavelength of X-rays can easily be obtained (d is known for a particular crystal C).

Photoelectric effect: *It is the phenomenon of the emission of electrons by metals when exposed to electromagnetic radiations* such as ultraviolet, *X-rays gamma-rays*, visible and infra-red light.

The electrons ejected in this manner are called photoelectrons because they are liberated by means of light.

Demonstration of photo electric effect: The apparatus used for this demonstration consists of an avacuated quartz tube, a metallic plate used as anode (A) and a photo-sensitive plate used as cathode (C). A galvanometer is used in the circuit to record the current when a light of suitable wavelength from a source is made to fall on the cathode.

Current starts flowing as indicated by the deflection of the galvanometer. This is

due to the light when it is made to fall on cathode and electrons are emitted from the cathode. These electrons are called photo electrons. These electrons are attracted by anode and current starts flowing.

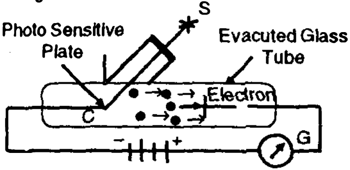


Fig.

Einstein's photoelectric equation: Einstein proves that when a single photon is incident on a metal surface, it is completely absorbed and imparts its energy *hv*. to a single electron. The photon energy is utalised for two purposes:

(i) Partly for getting the electron free from the atom and away from the

metal surface. This energy is known as the photoelectric work function of the metal and is represented by W_0

(ii) The balance of the photon energy is used up in giving the electron a kinetic energy of $\frac{1}{2}mv^2$.

$$hv = W_0 + \frac{1}{2}mv^2 = hv = hv_0 + \frac{1}{2}mv^2$$

where v_0 is called the threshold frequency.

De Broglie waves. De Broglie made a suggestion that matter like radiations has dual nature *i.e.* molecules, atoms, electrons and protons, might exhibit wave like properties under certain conditions. So, the matter behaves as particle under certain conditions and as waves in other circumstances.

The relation between the wavelengths λ of matter waves and the momentum (mr) of matter is given by $\lambda = \frac{h}{mv}$

where m is the mass of the particle moving with a velocity v. This is known as de Broglie wave motion.

Electron microscope. The limited resolution of optical microscope can be extended by electron microscope. Hence magnification is also increased tremendously.

In electron microscope, a fine beam of electron is used in place of light as in optical microscope. The focussing of electron beam is done by electromagnetic lenses. The principle of image formation is the same as in the optical microscope is shown in figure below.

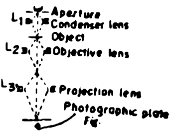


Fig.

SOUND

Sound waves: When a body vibrates in air, it forces the particles of air to vibrate. This produces *longitudinal* waves which are also called sound waves.

A disturbance that moves through matter is called mechanical wave. Sound waves are mechanical waves. Since the properties of sound waves depend upon the elastic properties of the medium, sound waves are also known as elastic waves.

Sound waves require: Sound waves can travel through solids, liquids and gases. But can not travel in vaccum.

The velocity of sound depends upon the density, elasticity and temperature of the medium. The velocity of sound in air at 0°C is 332 m/s, whereas as 20°C it is 343 m/s.

The velocity of sound is maximum in solids and minimum in gases. The velocity of sound at room temperature is nearly 5000 m/s in iron.

Velocity of light is about 3×10^8 m/s in air which is approximately 10^6 times that of sound. This is the reason why we see a flash of lighting much before the sound, of thunder.

Sources of sound: When any thing vibrates in air are (1) loudness (2) pitch (3) quality.

The loudness of sound depends upon the amplitude of the wave-greater the amplitude louder the sound.

Pitch: The property by virtue of which two sounds of same loudness can be distinguished is called pitch.

It is the property which tells whether a sound is sharp, dull or acute. The pitch of sound is determined by the frequency of the vibrating body producing sound.

Quality: The property by virtue of which we

differentiate between notes of same loudness and pitch is called quality. This depends upon the number of overtones or harmonics present in the note.

Audible range: Sound waves in the frequency range 20 Hz to 20,000 Hz which produces the sensation of hearing is called the audible range.

Ultrasonic waves: Waves with frequencies above the audible range are called ultrasonic waves. Waves with frequency above 20,000 Hz is ultrasonic wave.

Infrasonic waves: Infrasonic waves are the waves with frequencies below audible range *i.e.*, less than 20 Hz. Infrasonic waves are usually produced by large sources. Waves originating from earth quakes are example of infrasonic waves. It is said that audible frequency range of dogs is 15 Hz to 50,000 Hz.

Factors of the velocity of sound depends: The velocity of sound depends on density, elasticity and temperature. If the density of the gas is

increased the velocity of sound in it decreases. The velocity of sound in air increases on raising the temperature. Sound travels faster in humid air and slower in dry air.

Human ear: The car can be divided into three main parts. (i) The outer ear is the part outside the head. It receives sound

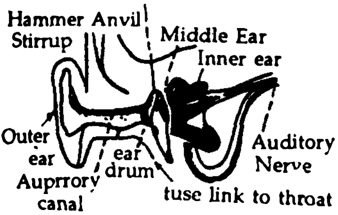


Fig.

waves. The waves pass through a little tunnel, called auditory canal, to the ear drum. The ear drum is a circular membrane about 0·01 cm thick. When

the sound wave strike the ear drum, it vibrates. These vibrations are passed on to the three tiny bones in the (ii) middle ear called the hammer, anvil and stirrup, in turn. The function of these bones is to increase the amplitude of vibrations produced by the ear drum. The stirrup finally passes these vibrations to the liquid in the (iii) inner ear.

These vibration press upon certain tissues called organs of corti. These organs change the pressure into nerve impulses. The impulses are carried to the brain by auditory nerve. The brain then intercepts these impulses as sound.

Free vibrations: The vibrations of a body when it vibrates with its own natural frequency are known as free vibrations.

Force vibrations: When a body *A* is forced to vibrate with a frequency, different from its own natural frequency, by the vibrations coming from another body *B*, the vibrations of body *A* are called forced vibrations. The frequency of the forced vibrations

is equal to the frequency of the body *B*.

Resonance: When a body is set into vibrations by an external periodic force whose frequency is equal to the natural frequency of the body, the amplitude of vibration increases at each step and becomes large. Such vibrations are called the resonate vibrations and the phenomenon as resonance.

Condition for Resonance: Because the sound has to travel down, the tube and back during one half vibration of the prong, the length of the air column for resonance must be one fourth of the wavelength of the sound emitted by the tuning fork.

If the length of air column is increased by

$$\frac{\lambda}{2}, \frac{2\lambda}{2}, \frac{3\lambda}{2} \ldots\ldots$$

etc. where λ is the wave length of sound in air, we will again obtain resonance in each case.

ELECTRICITY

Positively and negatively charged bodies: The nucleus of the atom carry positive charge and the surrounding electrons carry an equal amount of negative charge, so that ordinarily each atom is electrically neutral. The electrons surrounding the nucleus are loosely bound to it, hence, be easily removed by friction.

When ebonite rod is rubbed with fur, some electrons are transferred from fur to the ebonite rod. Due to deficit of electrons, fur becomes **positively charged** and due to excess of electrons the ebonite rod gets **negatively charged.** Like charges **repel** each other and unlike charges **attract** each other.

Electric induction: When an insulated

charged body is brought near an insulated neutral conductor, the near end of the conductor acquires opposite charge and the far end acquires similar charge. This is known as *electric induction.*

.***Charging a body by induction:*** Suppose a conductor *AB* is mounted on an insulating stand as shown below. Bring a positively charged glass rod near it, the negative charge in the conductor is attracted towards the glass rod while the positive charge is repelled. Thus the near end *A* of the conductor acquires negative charge and its far end *B* acquires positive charge. When the positively charged rod is removed, the conductor again becomes electrically neutral.

This shows that during induction equal and opposite charges are induced at the two ends of the conductor. Holding the positively charged rod near the conductor, if the far end is connected to earth with a connecting wire, as shown in Figure (*B*), the positively charge passes on

the earth as shown in fig. (*C*). Now if we first remove the connecting wire and then the charged rod, the negative charge spreads on the whole conductor as shown in Figure (*d*).

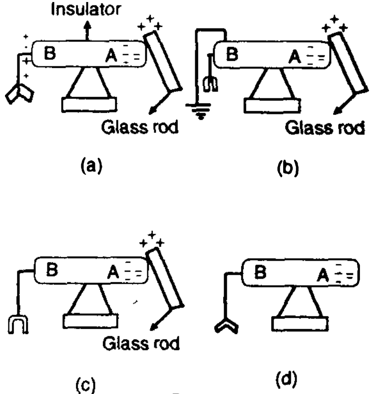


Fig.

Principle of conservation of charge: According to this principle the total amount of electric charge is conserved. It can neither be created nor destroyed. During electrification by friction, the process of rubbing does not create electric charges. Only the transfer of negative charge take place from one substance to another. The substance which losses negative charge becomes positively charged and the other which gains negative charge becomes negatively charged.

Conductors: The substances in which electric charges flow easily are called conductors, silver, aluminium, copper, graphite, human body etc. are good conductors of electricity.

Insulators: The substances in which electric charges do not flow easily are called insulators. Glass, wood, ebonite, sulphur, dry air, distilled water etc. are good insulators.

Coulomb's Law: deals with the force of attraction or repulsion between station-

ary charges, the charges at rest. According to his law, the force of attraction or repulsion acting between two point charges is (i) directly proportional to the product of the magnitudes of the charges and (ii) inversely proportional to the square of the distance between them. If two point charges q_1 and q_2 *are separated by distance r* in vacuum, then force acting between them is given by

$$F \propto q_1 q_2$$

$$F \propto \frac{1}{r^2}$$

$$F = k\frac{q_1 q_2}{r^2}$$

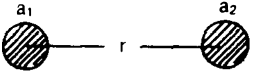


Fig.

where *k* is a constant of proportionality.

In S.I. units charge is measured in coulomb's, the force in Newton's (N) dis-

tance in meters (m) the value of k when the charges are situated in vacuum or air is $9 \times 10^9 \ N.m^2/C^2$.

For charges in any other medium,

$$F = 9 \times 10^2 \frac{q_1 q_2}{kr^2}$$

where the constant k is called dielectric constant of the medium, $k = 1$ for air $k = 6$ for mica and $k = 81$ for water.

Coulomb charge is that charge which would repel an equal and similar charge placed at a distance of one meter from it in vacuum or air with a force of 9×10^9 N.

Principle of superposition: According to this principle the force on a charge at any point due to number of other charges is the vector sum of the forces which would be exerted by the individual charges on the charge at that point. Consider three bodies carrying charges q_1, q_2 and q_3 as shown in Figure.

To calculate the force on charge q_1 exerted by q_2 and q_3, using coulbom's law, we

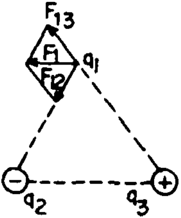


Fig.

first calculate the force on q_1 due to q_2 when q_3 is far away. Then we take q_2 away and bring q_3 in its original position and determine the force on q_1. According to principle of super-position the net force exerted by charges q_2 and q_3 on q_1 is the vector sum of the forces independently exerted by q_2 and q_3 on q_1 i.e.,

$$\vec{F_1} = \vec{F_{12}} + \vec{F_{13}}$$

Electric field: The space around a charged body within which it can exert a force on another charged body, is its electric field.

Electric field intensity: The intensity of the electric field at a point is defined as the force experienced by a unit positive charge when placed at that point. If a small test charge q_0 experiences a force F at in an point an electric field, then the intensity E of the electric field at that point is given by, $E = \frac{F}{q_0}$. The direction of the electric intensity is that of the force on the unit positive charge. The S.I. unit of electric intensity is ***Newton per Coulomb*** (N/C). *It is a vector quantity* and has the same direction as that of the force on a unit positive charge.

Electric lines of force: The path traced by a test charge free to move under the effect of an electric field is called a line of force. The line of force is a curve so drawn that a tangent to it at any point gives the direction of the resultant electric field at that point.

Properties of electric lines of force:

(i) A line of force starts from a positive

charge and ends on a negative charge.

(ii) No two lines of force cross each other

(iii) A line of force is always normal to the surface of the conductor.

(iv) The lines of force do not pass into a closed conductor

(v) The lines of force contract lengthwise and expand side wise

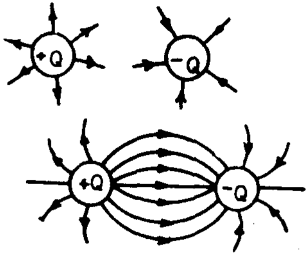


Fig.

(vi) The direction of force is given by the direction in which a free positive charge tends to move.

Electric potential Electric potential plays the same role in the flow of charge as is played by the level in the flow of water. The direction of flow of charge depends on the potential of the two charged bodies. Charge flows from a body at

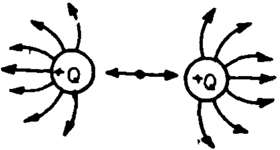


Fig.

higher potential to a body at comparatively lower potential. Thus electric potential is that electrical condition which determines the direction of flow of charge.

The electric potential at a point in an electric field is measured by the amount

of work done in taking a unit +ve charge from infinity to that point against electric forces.

Unit of potential: The unit of potential is volt. The potential at a point is 1 volt if 1 Joule of work is done in bringing 1 coulomb of +ve charge from infinity to that point. Electric potential is a **scalar quantity.**

Potential difference: The potential difference between two points in an electric field is defined as the amount of work done in moving a unit positive charge from one point to the other.

If W amount of work is required to move a charge Q from one point to another in the electric field, then the potential difference between the two points is given by $V = \frac{W}{Q}$ or $W = QV$. The S.I. unit of potential difference is volt.

Electric current is defined as the rate of flow of charge through any section of a

conductor. If a charge Q passes through any section of a conductor in time t, then the current flowing through it is given by,

$I = \frac{Q}{t}$. The unit of current is **ampere.**

Relation between electric charge, time and electric current. Electric current

$$(I) = \frac{\text{charge } (Q)}{\text{time } (t)}.$$

Ampere: When one coulomb of charge flows through any section of a conductor in one second, the current flowing through said to be one ampere.

$$1 \text{ ampere} = \frac{1 \text{ coulomb}}{\text{second}}$$

Electric circuit: The closed path along which an electric current flows is called an electric circuit.

Electric resistance: The electric resistance of a conductor is the property of the conductor by virtue of which it opposes the flow of current through it.

$$\text{Resistance } (R) = \frac{\text{Potential difference } (V)}{\text{Current } (I)}$$

The S.I. unit of resistance is ohm (symbol Ω). If $V = 1$ *volt*, $I = 1$ *ampere then* $R = 1$ ohm. Hence, a conductor has a resistance of 1 ohm if a current of 1 ampere flows through it when a potential difference of 1 volt is applied between its two ends.

Effect of temperature on resistance: The resistance of a conductor increases with the rise of temperature while in case of semi-conductors the resistance decreases with temperature.

Ohm's Law: This law states that the current passing through a conductor is directly proportional to the potential difference across its ends provided the temperature and other physical conditions remained unchanged. If I be the current passing through a conductor with a potential difference V across its ends, then ohm's law can be expressed as

$$V \propto I$$

$$V = RI \text{ or } R = \frac{V}{I}$$

Figure shows the experimental verification of ohm's law. The current in the circuit is varied by adjusting rheostate Rh and the corresponding readings of

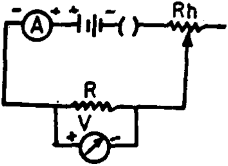


Fig.

voltmeter and ammeter is noted. If a graph is plotted between the potential difference (V) and current (I), it will found to be a straight line showing that $V \propto I$

This verifies ohm's law.

Limitations of ohm's law:

(i) Only small current should be allowed to flow through the circuit so that

temperature should remain constant.

(ii) The conductor should not be subjected to any kind of stress or strain or tension.

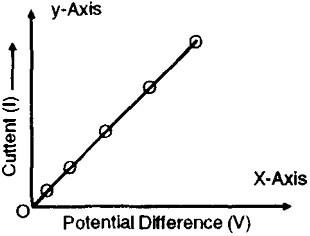


Fig.

Symbols used in circuit diagrams:

Cell	Galvanometer
Battery of cells	Ammeter
Switch	Voltmeter
Open key plug	Voltameter
A closed key plug	An electric bulb

Reverse switch	One wire crossing another
Resistor	Wires joined
Rheostat (Variable Resistance)	

Resistors in series: When a number of conductors connected end to end so that the same current passes through each conductor, they are said to be connected in series. $R = R_1 + R_2 + R_3$

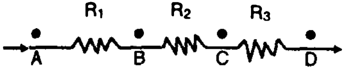


Fig.

When a number of resistors are connected in series, the equivalent resistance (R) of the combination of resistors is equal to the sum of the individual resistances of the resistors.

Resistors in parallel: When a number of conductors (resistors) are connected in such a way that one terminal of each conductor is connected at one common

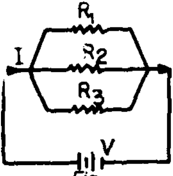


Fig.

point *A* and similarly other terminal of each conductor is connected at the another common point, *B*, then they are said to be connected in parallel.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

When a number of resistors are connected in parallel the reciprocal of the equivalent resistance of the combination is equal to the sum of the reciprocal of the individual resistances of the resistors.

This is also known as law of resistances in parallel.

Specific resistance: The resistance of a conductor depends upon its length, cross-sectional area and temperature of the conductor. It was shown by Ohm that the resistance of a conductor at constant temperature obeyed the following two laws:

(i) *Law of length.* The resistance of given conductor or wire of certain cross-section area is directly proportional to its length of a conductor, greater is its resistance.

(ii) *Law of thickness.* The resistance of a given conductor or wire of certain length is inversely proportional to its cross-sectional area i.e., thinner is the conductor or wire greater is its resistance.

If the resistance of a wire of length 1 and cross-section area a is R, then from the law of length

$R \propto l$, where 'a' is constant

and law of thickness

$$R \propto \frac{1}{a} \text{ where 'l' is constant}$$

Combining the two laws we get

$$R \propto \frac{1}{a} \quad \text{or} \quad R = \rho\frac{1}{a}$$

if $a = 1, l = 1$ then $\rho = R$

Specific resistance or resistivity: of a material is the resistance of a conductor made of that material of unit length and unit area of cross-section.

Heating effect of current: Whenever electric current passes through a conductor, the part of the electrical energy is converted into heat energy because the resistance is offered by the conductor to the flow of current similar to the production of heat when a body moves against friction.

Joule's law of heating: Joule found that the amount of heat H produced in a conductor is directly proportional to the following factors

(i) Square of current I flowing through the conductor

(ii) Resistance R of the conductor and

(iii) Time t for which the current flows.

$H \propto I^2 Rt$ this relation is called Joule's law

$H \propto = \frac{I^2Rt}{J}$ (in calories) and $J = 4{\cdot}12$

Electric power: The electric power of an appliance is defined as the rate of consumption of electric energy or as its rate of doing work.

$p = \frac{W}{t}$ where W is the electric work done in time t

$$W = I^2Rt \quad \therefore \quad \sqrt{x}P = \frac{W}{t} = I^2R = VI$$

$$(\because V = IR)$$

The S.I. unit of power is watt, I watt

$$= \frac{1 \text{ joule}}{\text{second}}$$

or 1 joule = 1 watt. The commercial unit of electric energy is kilowatt hour.

1 kilowatt hour

$$= 1000\ J/s \times 3600\ s = 3{\cdot}6 \times 10^6 J.$$

Simple voltaic cell: An electrical cell is a device in which chemical energy is converted into electrical energy. This electrical energy is then used to derive an electric current through a circuit. A simple form of an electric cell was designed for the first time by an Italian scientist named Volta in 1794 and after his name this cell is known as simple voltaic cell.

It consists of two plates, one of copper and the other of zinc both dipped in a vessel containing dilute sulphuric acid. These plates are separated from each other as shown in Fig. These metallic plates are called electrodes. The copper plate is called the **positive electrode** whereas zinc plate is called the **negative electrode.** The liquid (dilute H_2SO_4) is called the **electrolyte.** The two plates

have finding screws at their top which help in connecting the two electrodes by means of wire. When these two electrodes are joined by means of a copper wire, an electric current (conventional) flows from copper to zinc outside the vessel and from zinc to copper inside the

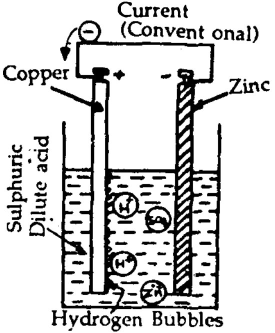


Fig.

vessel as shown in Fig. This shows that copper plate is at a higher potential than zinc plate.

Theory of the Voltaic Cell: When copper and zinc plates are connected by a wire, zinc slowly starts dissolving in sulphuric acid and the bubbles of hydrogen are formed on the copper plate. At the same time electrons flow through the wire from zinc to the copper as shown in Fig. It may be noted here that the direction of the conventional current is opposite to the direction of the electronic current, we know that the flow of charges from one point to another point takes places only when there exists a potential difference between the two points.

Electrolysis: Water in its pure form is a bad conductor of electricity and so is the case with most of the liquids. The solutions of acids, basis and salts are however, good conductors of electricity. These solutions undergo a chemical decomposition when electricity passes through them. For ex-

ample, when an electric current is passed through acidulated water (i.e. the water in which acid has been added), it gets decomposed into oxygen and hydrogen. Bubbles of hydrogen gas are given off from the solution where the current enters the solution and oxygen bubbles appear at the point where the current leaves the solution. The process of decomposition of a substance by the passage of electric current through it is known as **electrolysis.** The substances which under go chemical decomposition due to the passage of current through them are known as electrolytes. In the above example acidulated water is electrolyte. Electrolytes are mostly in the form of liquids.

Electroplating: One of the most important practical application of electrolysis is electroplating. *This is the process by which a thin coating of any desired metal can be deposited on another metallic object.* The articles of iron which easily

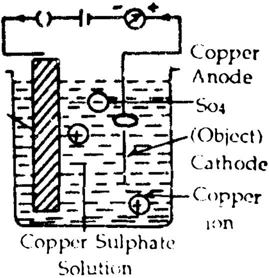


Fig.

gets rusted or of brass which corrode in air, are given a thin coating of nickel or chromium. Nickel and chromium are the metals which do not rust or corrode. Cheap ornaments or metals etc are gold-plated or silver plated to make them attractive. To understand how electroplating is done, let us consider below

example of copper plating of a metal object.

The electrolyte used in copper plating is a solution of copper sulphate which is slightly acidified (i.e. a small quantity of acid is mixed in it). The object which is to be copper plated is dipped in the electrolyte and is made cathode as shown in Fig. A rod of pure copper is made the anode. The solution contains both copperions (Cu^{++}) and sulphate ions (SO_4—). On the passage of electric current through the electrolyte Cu^{++} ions are transported to the cathode. On the cathode (Cu^{++}) neutralise their positive charge and layer of copper gets deposited on it.

The sulphate ions (SO_4—) are drawn toward the anode. At anode S Q— neutralise their charge, react with the copper and produce copper sulphate. Thus we see that copper is effectively removed from the anode and deposited

on the cathode. This is how copper-plating is done. The same type of process is used for silver, nickel and chromium plating of metal objects.

Magnet: A substance which possesses the property of attracting small pieces of iron such as iron fillings, paper clips hair pins etc. and sets itself in North-South direction when suspended freely is called a magnet.

Magnetism: The phenomenon by which this attraction takes place is called magnetism.

Types of magnets: Magnets are of two types:

(1) Natural magnet (2) Artificial magnet.

(1) The iron ores obtained from the mines and having the property of attracting iron pieces are called *natural-magnets.*

(2) Those magnets which are created by artificial means are called *artificial magnets.*

Poles of a magnet: The attracting power of a magnet appears to be concentrated at definite regions near the ends and these regions are called poles. It should be noted that pole of a magnet is a region

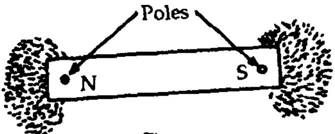


Fig.

and not a definite point, but for the purpose of calculations, it is generally assumed to be located at a point near the end of a magnet.

North and South Pole: The pole which points towards north is called the **north pole** (N-pole) and the pole pointing towards south pole is called **south pole** (S-pole).

Magnetic axis: The imaginary line passing through the north (*N*) and south (*S*) poles

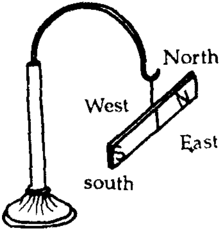


Fig.

of a magnet is called the *magnetic axis* is a magnet.

Magnetic equator: A line which is perpendicular bisector of the line joining the two poles is called magnetic equator of the magnet.

Magnetic length: The distance between the two poles of a magnet is called its *magnetic length*. It is smaller than its geometrical length because the poles are not situated exactly at the ends but

are situated near the ends a little inside the magnet.

Properties of a magnet:

(i) A magnet attracts small pieces of iron.

(ii) It sets itself in North-south direction when pivoted or suspended freely.

(iii) The poles of a magnet always occur in pairs.

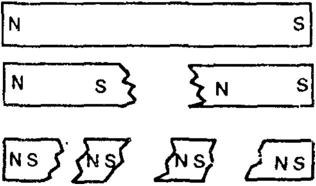


Fig. On breaking a bar magnet each component developes a pair of poles.

(iv) Like poles repel and unlike pole attract.

Magnetic field: The space around a magnet in which its influence is felt is called the magnetic field.

Magnetic Induction: A magnet possesses the property of inducing magnetism into some other substances (made of certain materials) placed near it even without touching it. This property of a magnet to induce magnetism into other magnetic materials is called magnetic induction.

Properties of lines of force:

(i) Lines of force start from North pole and end on South pole in the magnetic In the magnetic field. But inside the magnet the direction is from south to north.

(ii) Two lines of force never intersect each other.

(iii) Magnetic lines of force are crowded. together near the poles where the field is strongest and are spread out further away where the field is

Fig.

weaker.

(iv) Magnetic lines of force tend to contract longitudinally *i.e.* they tend to shorten in length. The longitudinal contraction of the magnetic lines of force accounts for the attraction between unlike poles, for it would pull the unlike poles together.

(v) Magnetic lines of force proceeding in the same direction to repel each other laterally at right angles to their lengths. This lateral repulsion accounts for the repulsion between like poles, for it would push the like poles apart.

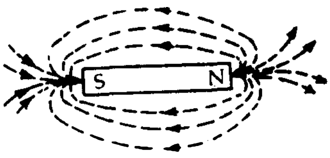


Fig. Magnetic lines of force due to a bar magnet.

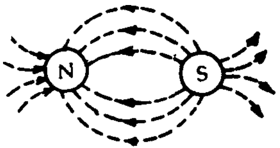


Fig. Magnetic lines of force due to two unlike poles placed close to each other.

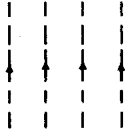


Fig. Magnetic lines of force due to a uniform magnetic field.

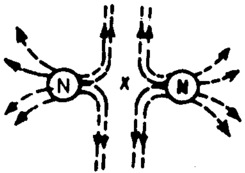


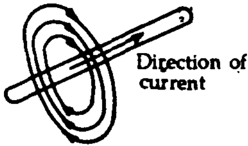
Fig. Magnetic lines of force due to two like poles placed close to each other.

Magnetic effect of an electric current: Oersted discovered that when an electric current is passed through a conductor of

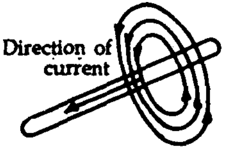
any shape, there is a magnetic field around it. This is called the magnetic effect of the electric current.

Right Hand Rule for the direction of the magnetic field due to current: Hold the wire a carrying electric current in the right-hand so that the thumb points in the direction of the current; then the direction in which the fingers give the direction of the magnetic lines of force.

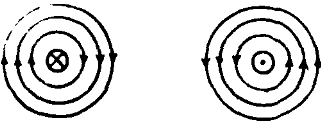
Magnetic lines of force due to straight wire carrying current: Look at the Figure (a), (b), (c) and (d). The direction of magnetic lines of force can be found out by applying "Right hand rule."



(a)



(b)



(c) Current directed away from the observer

(d) Current directed Towards an observer

Fig.

Magnetic lines of force: The field in a plane perpendicular to the coil passing it centre is as shown in Figure and is similar

to that due to a short bar magnet. The lines of force around and near the points where the wire passes through the cardboard are almost circular, their direction being given by right hand rule.

Over a small region at the centre of the circular coil the lines of force are straight; parallel to themselves and perpendicular to the plane of the coil. The magnetic *field* at the centre of a circular coil carrying current is uniform and perpendicular to the plane of the coil.

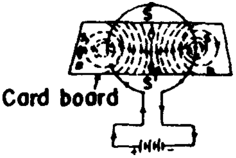


Fig.

S.I. unit of magnetic field: It is Tesla (T). Magnetic field is usually denoted by B. Oersted is the C.G.S. unit of magnetic

field. Oersted is also called Gauss.

$$1 \text{ Gauss} = 10^{-4}\ T$$

Expression for magnetic field at a point distance r from an infinitely long straight conductor carrying current I.

is $$B = \frac{\mu_0 I}{2\pi r}$$

where μ_0 is a constant and is called the permeability of vacuum and its value is $4\pi \times 10^{-7}\ Tm/A$.

Fleming's Left Hand Rule. For this extend the **thumb, middle** finger and **fore**

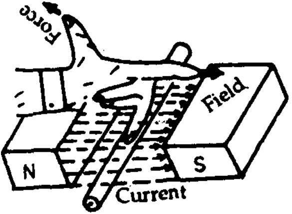


Fig.

finger of the left hand so that all three are mutually perpendicular to one another. Point fore finger in the direction of the **field**, the middle finger in the direction of the **current** and the thumb points in the **direction of the force** exerted on the conductor.

A straight conductor of the length l carrying a current I placed perpendicular to a magnetic field of strength B experiences a force F given by

$$F = BIl$$

Cyclotron: The cyclotron is a machine used to accelerate the charged particles. Its principle is based upon the motion of charged particles is a magnetic field. When a moving charged particle enters a magnetic field which is perpendicular to both its velocity and the field. Thus it is deflected from its path. If the field is uniform and the particle move in a plane normal to its path, become circular. The radius of the path depends upon the velocity of the particle *i.e.*, the radius of

the circle being larger for higher energies.

Van Alen radiation belt: A vast zone in the equitorial regions, high up in the atmosphere where charged particles are

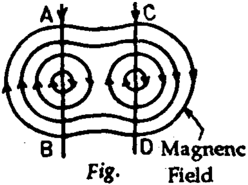


Fig.

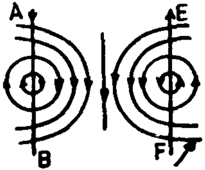


Fig.

trapped by the earth's magnetic field is called Van Allen radiation belt.

(i) Two parallel wires carrying current in the same direction attract each other.

(ii) Two parallel wires carrying current in the opposite directions repel each other.

(iii) Expression for the force of attraction or repulsion between two long conductors carrying current kept at a distance r parallel to each other is

$$F = \frac{\mu_0 I_1 I_2}{2\pi r}$$

where $\mu_0 = 4\pi \times 10^{-7}\ N/A^2$

Galvanometer: Instruments used for detecting and measuring electric currents are called galvanometers. A moving coil galvanometer is based on the principle that when a current carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by the Fleming's left hand rule as told above.

Dynamo: A dynamo transforms mechanical energy into electrical energy. It works on the principle of electromagnetic induction. When a coil is rotated in a magnetic field the lines of force cutting by the coil changes due to which an induced current is set up in the coil. The direction of the induced current is given by the Fleming's right hand rule.

Construction of a simple dynamo is shown in figure.

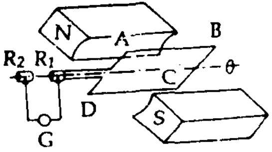


Fig.

Ammeter: It is a device which is used to measure current through a circuit To convert a galvanometer into an ammeter,

a suitable low resistance is connected in parallel with the galvanometer which is called a shunt and the scale is directly graduated in ampere. Ammeter is always connected in series.

Voltmeter: It is a device which is used to measure p.d. across two points in a circuit. To convert a galvanometer into voltmeter, a suitable high resistance is connected in series with the galvanometer coil and the scale is directly caliberated in volts. Voltmeter is always connected in parallel.

Electric fuse: An electric fuse is safety device meant to protect an electric circuit

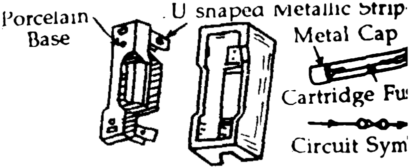


Fig.

from being demaged due to excessive current which may be caused due to the voltage fluctuations or faulty wiring or the use of poor quality of wire.

Cartridge fuse: A cartridge fuse consists of a small glass tube with a fuse wire inside connected to the metallic caps at the ends. It is connected to a live wire leading to the appliance.

Magnetic meridian: A vertical plane passing through the axis of the freely suspended magnet is called magnetic meridian.

Geographic meridian: A vertical plane passing through geographical north-south *(i.e., passing through the geographical axis) of the earth is called the geographic meridian.*

Declination: The angle between the magnetic meridian and geographical meridian is called the declination. Its value is different at different places on the earth. θ is the declination.

Angle of dip: It is the angle between the earth's resultant magnetic field and its horizontal component, or in other words, it is the angle which the axis of a freely suspended magnet makes with the horizontal. The angle δ between AB and AE is the angle of dip.

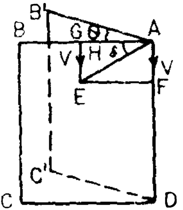


Fig.

Dip circle: It is an instrument which is used to determine angle of dip at a place.

Magnetic equator: It is the line passing through the points on the surface of the

earth where the angle of dip is zero. The value of dip at the poles is 90° and on the equatorial line is 0°.

Horizontal component of earth's magnetic field: The earth's magnetic field at a place may be resolved into two rectangular component (i) the horizontal component (H) and (ii) the vertical component (V). The horizontal component of earth's magnetic field is of the magnetic elements of earth's magnetism. The value of H is zero on the poles.

Heat Produced: When electric current is passed through a resistance (R_2) heat produced (H) is given by $H = I^2 Rt$

where t = time of flow of current

R = resistance of the material

and I = current flowing through the material

Power: Rate of doing work is called power(P)

or $$P = \frac{W}{t} = \frac{I^2Rt}{t} = I^2R$$

Power is measured in watt or killo watt.

Kilowatt hour: It is the unit of electricity

$$1 \text{ kWh} = 3.6 \times 10^6 \text{ J.}$$

Graph between V and I: As shown in Fig. 9.4 The graph between V and I is a straight line. The slope of the curve gives the resistance.

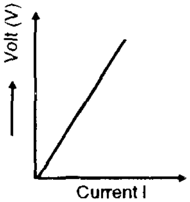


Fig.

Conductors: The materials that offer negligible resistance to the flow of currents.

Silver copper and aluminium are good conductors.

Insulators: The materials that do not allow any electricity to pass through them are known as insulators. Rubber, plastics and wood are excellent insulators.

Electromagnetism: Magnetism produced by the effect of the electricity. The direction of magnetic field can be known by (*a*) Maxwell's cork screw rule and (*b*) Right hand thumb rule.

Maxwell's cork screw Rule: Below fig shows a right hand screw placed in the direction of flow of current. Now rotate the cork screw such that it advances in the direction of the flow of current. The

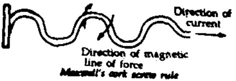


Fig. Maxwell's cork screw rule

direction of rotation of the thumb gives the direction of flow of current.

Verification of Ohm's Law: Ohms law can be verified frυm the circuit as shown in fig. (a). Set on one cell in the circuit and note the current *I* and potential difference *V* across the points *A* and *B*. Now connect two cells and note the current *I* and potential difference V cross the points *A* and *B*. Repeat the experiment with 3, 4, 5, 6 and 7 cells. In all these cases it will be seen that the ratio is the same.

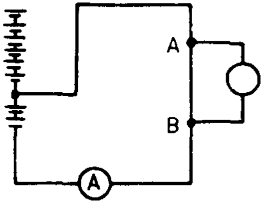


Fig.

or $$\frac{V_1}{I_1} = \frac{V_2}{I_2} = \text{........}\frac{V_n}{I_n}$$

If a graph is plotted between V and I it will be a straight line as shown in Fig. (b)

It means $V = IR$

where R = resistance of the wire

It verifies Ohm's law.

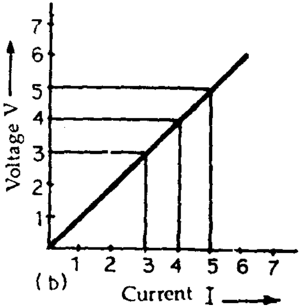


Fig. Verification of Ohm's law

Heating effect electric current: When an electric current is passed through a circuit, then

Work done = potential difference × current × time

or $W = V.I.T$

where W = work done

V = potential difference

T = time of flow of current

also $V = IR$

Hence $W = IRIT = I^2RT$

This work done in an electric circuit appears in the form of heat. Thus heat produced by an electric circuit is proportional to

(i) square of the current flowing in it

(ii) resistance of the wire and

(iii) time of flow.

The above equation of heat is used in all electrical heating devices like electric bulbs, heaters, electric iron, immersion heaters and cooking ranges.

Oersted's experiment: Oersted discovered that magnetic field is produced around the wire when a current is passed

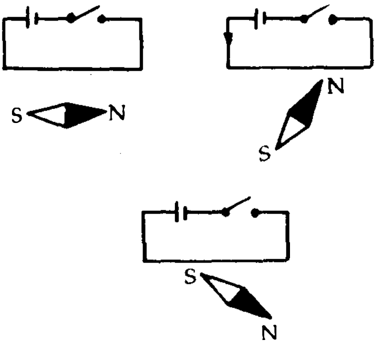


Fig. Oersted's experiment. Generation of magnetic field around a current carrying conductor (wire).

through a conducting wire. He verified his law from the following experiment. He placed a magnetic needle below the circuit as shown in Fig. (*a*). As shown in fig. (*b*) when current was passed through the wire, the needle was deflected towards one side.

The direction of flow of current was reversed as shown in Fig. (c). The magnetic needle was deflected towards the other side. It verifies Oersted's experiment of generation of magnetic field around the current carrying wire.

Magnetic field : Fig. below shows the set up for verifying, that magnetic field is

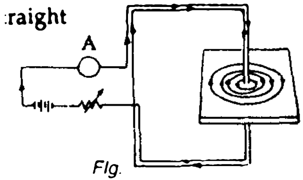


Fig.

produced when current is passed through a straight conducting wire.

The copper wire is passing through a horizontal card board. With the help of a rheostat, allow a current of 2 ampere to pass through the circuit. Now place the compass needle in various positions on the card board around the wire.

Draw the direction of lines of force with the help of magnetic needle. Reverse the direction of flow of current. Now the magnetic needle will point in the reverse direction. The direction of magnetic field is given by Maxwell's cork screw rule. It states as follows.

Fig. below shows the current carrying conductor held in the right hand such that

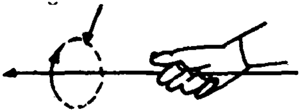


Fig. Maxwell's right hand screw.

the current flows away from the body. The direction of the fingers points towards the direction of flow of magnetic lines of force.

Faraday's experiment: Faraday showed that rotational motion can be produced in a live conductor by a magnet. The experimental set up of Faraday is shown in Fig. It consists of a moving wire immersed in mercury. When current is passed, the wire starts rotating around the magnet.

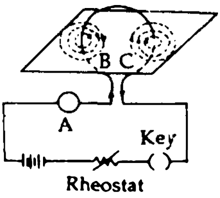


Fig.

It means that an electric motor converts electrical energy into mechanical energy. An electric motor works on the principle, "when an electric current is passed

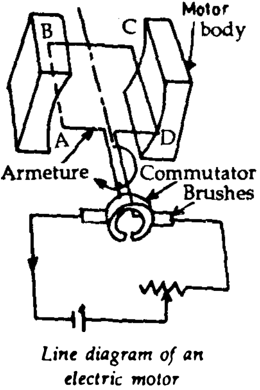


Fig. Line diagram of an electric motor

through a conductor kept normally in a magnetic field, a force acts on the conductor, as a result of which the conductor begins to move."

Fig. shows the simple line diagram of an electric motor. It consists of a rectangular coil ABCD wound on an armature. The armature rotates about the spindle between the poles of a magnet. The coil is connected to the slip rings (the commutator). When current is passed through the circuit, magnetic field is set up. It pushes the part CD downwards and AB upwards *i.e.*, the motor starts rotating in the clockwise direction. After half rotation, the polarity of commutator changes. This reversal of polarity pushes AB downwards the CD upwards. The process repeats rapidly and the electric motor begins to rotate.

Electric Power Plants: The plants where electricity is produced are known as electric power plants. In nuclear power plants, electricity is produced by nuclear

fission. In hydro power stations, the kinetic energy of the filuid is converted into electrical energy. In thermal power plants, the heat produced by burning coal is utilised for the production of electricity. In hydel power plants energy of steam is converted into electrical energy.

Coulomb's law: States that the force of attraction or repulsion between two charged bodies is directly proportional to the product of charges on them and inversely proportional to the square of the distance between them and the force is acting along the two charges.

If two charged bodies having charges q_1 and q_2 be sepa-rated by a distance '*d*' then force

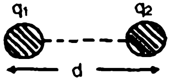


Fig.

$$F = k\frac{q_1 q_2}{d^2}.$$

where *k* is a constant depends upon (i) the nature of the intervening medium and

(ii) the unit system adopted. In S.I. system of units, value of k has been experimentally found as $9 \times 10^9\ Nm^2/C^2$ for free space (*i.e.*, vacuum)

For free space,

$$F = 9 \times 10^9 \frac{q_1 q_2}{d^2} = \frac{1}{4\pi\varepsilon_0} = \frac{q_1 q_2}{d^2}$$

where ε_0 O is called the permittivity of free space.

$$\varepsilon_0 = \frac{1}{4\pi \times 9 \times 10^9} = 8.85 \times 10^{12}\ C^2\ N^{-1}\ m^{-2}$$

Relative permittivity or dielectric constant: If we find force between two charges in a given medium, the force F is reduced by a factor ε, compared with its value in vacuum.

This constant ε_r is called the relative permittivity or the dielectric constant of the medium.

$$F = \frac{q_1 q_2}{4\pi\varepsilon_0\varepsilon_r d^2} = \frac{q_1 q_2}{4\pi\varepsilon d^2}$$

where $\varepsilon = \varepsilon_0\varepsilon_r$ and is called permittivity

(or absolute permittivity) of the given medium.

Electric field: of a given charged conductor is that space around it, in which it influences any other charged body if brought.

Electric intensity or (electric field strength): at a point in an electric field is defined as the electric force experienced by unit charge (positive) placed at that point.

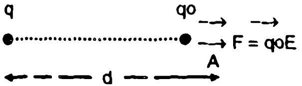


Fig.

If $\vec{F}$ be the force experienced by test charge, then electric intensity $\vec{E}$ at that point is

$$\vec{E} = \frac{\vec{F}}{q_0}$$

Intensity of the electric field at point *A*

situated in free space is given by.

$$E = \frac{F}{q_0} = \frac{q}{4\pi\varepsilon_0 d^2}$$

Electrostatic potential: At a point in a given electric field is the work done by the force of the electric field per unit positive charge moved from that point to a place at zero potential.

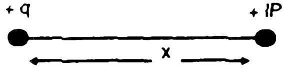


Fig.

In free space value of electric potential V at a point x distance apart from the given charge q is given by

$$V = \frac{q}{4\pi\varepsilon_0 x}$$

Electric potential is a scalar quantity. Its unit is

$$1 \text{ volt} = \left(\frac{1 \text{ joule}}{1 \text{ coulomb}}\right)$$

Relation between field intensity and potential: Electric field intensity E at a point may be considered as negative of the gradient of electric potential at that point.

$$E = \frac{dV}{dx} = - \text{ (potential gradient)}$$

Electric intensity between two parallel charged plates: is $V = E.\ d$ or Electric intensity.

$$E = \frac{\text{potential difference } V}{\text{distance between the plates } d}$$

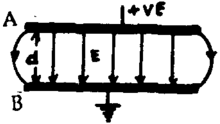


Fig.

Electron volt(eV): An electron volt is the energy acquired by an electron when accelerated by a potential of one volt.

$$W = qV \text{ Joules}$$

where W is the energy acquired by charge. q is the charge in coulomb and V is potential difference

$$1\ eV = 1.6 \times 10^{-19} \times 1 = 1.6 \times 10^{-19}\ J.$$

Electric current: or strength of electric current is defined as the rate of flow of electric charge through any section of the wire. If dq units of electric charge flows across any section of the wire in dt second, the strength of the current is given by $i = \frac{dq}{dt}$

Conventional direction of electron of electric current: According to the convention the direction of current is taken as the direction of flow of positive charge. But motion of negative charge from right

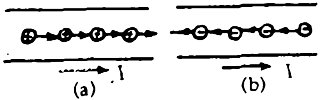


Fig.

to left is equivalent to motion of positive charge from left to right as shown.

Unit of current is 1 ampere. We say current is one ampere if rate of flow of charge through a cross-section of a given conductor is 1 coulomb per second. Or

In terms of flow of electrons we may define 1 ampere current as the rate of flow of 6.25×10^{18} free electrons per second through a cross-section of a conductor.

According to the form adopted by International Committee on Weights and Measures ampere is that steady current which, flowing in two infinitely long, straight, parallel conductors of negligible circular cross-section, placed 1 metre apart, in vacuum produces a force between them of 2×10^{-7} newtons per metre length of conductor.

According to yet another definition one ampere is defined as that current which will deposit 0.001118 gram of silver on

the cathode of a silver voltameter in 1 second.

Drift velocity: May be defined as the velocity of the free electrons with which they get drifted towards the positive terminal under the influence of the external field. The drift velocity of electrons is given by $V_4 = \frac{Eet}{m}$

where $\vec{E}$ is applied field between the two ends of a conductor, e is the charge on an electron, *m is the mass of the electron and t* is the average time spent between the two consecutive collision.

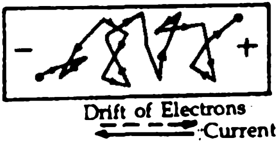


Fig.

Relation between current and drift velocity:

$$i = \frac{q}{t} = \frac{nAle}{l/v_d}$$

or $\quad i = n\,Aev_d$

where $\quad l$ = wire length

A = area cross section in which free electrons flow to the right with drift velocity v_d

n = no. of electron present in a unit volume of the wire.

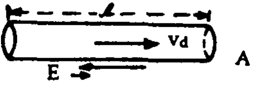


Fig.

Electric resistance: The electric resistance of a conductor is the property of the conductor by virtue of which it opposes the flow of current through it.

$$\text{Resistance } (R) = \frac{\text{Potential difference } (V)}{\text{Current } (I)}$$

The S.I. unit of resistance is ohm (symbol Ω): If $V = 1$ volt, $I = 1$ ampere then $R = 1$ ohm. Hence, a *conductor* has a resistance of ohm if a current of 1 amp. flows through it when a potential difference of 1 volt is applied between its two ends.

Specific resistance: The resistance of a conductor depends upon its length, cross-sectional area and temperature of the conductor. It was shown by Ohm that the resistance of a conductor at constant temperature obeyed the following two laws:

(i) Law *of length*. The resistance of a given conductor or wire of certain cross-section area is directly proportional to its length i.e., greater is the length of a conductor, greater is its resistance.

(ii) Law *of thickness:* The resistance of a given conductor on wire of certain

length is inversely proportional to its cross sectional area *i.e.*, thinner is the conductor or wire greater is its resistance.

If the resistance of a wire of length l and cross-section area a is R, then from the law of length

$R \propto l$, *where 'a' is constant*

and law of thickness

$R \propto \frac{1}{a}$ where 'l' is constant

Combining the two laws, we get

$$R \propto \frac{l}{a} \quad \text{or} \quad R = \rho \frac{l}{a}$$

If $a = 1$, $l = 1$ then $\rho = R$

Specific resistance or resistivity: of a material is the resistance of a conductor made of that material of *unit length and unit area* of cross-section.

Conductivity: of a given material is the inverse of its resistivity.

Conductivity $\sigma = \frac{1}{\rho}$ unit is

$$\frac{1}{ohm.m} = ohm^{-1}\,m^{-1}$$

Conductance: Inverse of resistance of a given conductor is called its conductance. Its unit is $\frac{1}{ohm}$ or mho.

Shunt: is a small resistance always connected in parallel with the main circuit so as to reduce the current in main circuit.

Distribution of current between a galvanometer and shunt:

$$I_3 = \frac{IG}{(S + G)}$$

where I_s is the current through shunt, I is the total current, G is the resistance of galvanometer and S is the resistance of shunt.

Heating effect of current: Whenever electric current passes through a conductor, the part of the electric energy is converted into heat energy because the

resistance is offered by the conductor to the flow of current similar to the production of heat when a body moves against friction.

Joule's law of heating: Joule found that the amount of heat H produced in a conductor is directly proportional to the following factors.

(i) Square of current I flowing through the conductor

(ii) Resistance R of the conductor and

(iii) Time t for which the current flows.

$H \propto I^2 RT$, this relation is called Joule's law

$H = \frac{I^2 Rt}{J}$ (in calories) and J = 4.12

Electric power: The electric power of an appliance is defined as the rate of consumption of electric energy or as its rate of doing work.

$P = \frac{W}{t}$ where W is the electric work done in time t

$$W = I^2 Rt$$

$$\therefore \quad P = \frac{W}{t} = I^2 R = VI \qquad (\because V = IR)$$

The S.I. unit of power is watt, 1 watt $= \frac{1 \text{ joule}}{\text{second}}$ or 1 joule = 1 watt. The commercial unit of electric energy is kilowatt hour.

1 kilowatt hour = 1000 J/s × 3600 s $= 3.6 \times 10^6$ J

Electrical energy: It is the total electrical energy consumed when a current flows through a conductor for a given time.

Electrical energy W = VIt = Pt

If 1 kilowatt power is used for 1 hour, energy consumed will be 1 kilowatt hour

$$\begin{aligned} 1 \text{ kWh} &= 1 \text{ kw} \times 1 \text{ hr.} \\ &= 1000 \times 3600 \text{ sec.} \\ &= 3.6 \times 10^6 \text{ joules.} \end{aligned}$$

Effect of temperature on resistance: The resistance of a conductor increases with the rise of temperature. If R_0 and R_t are the resistances offered by a conducting pure

metal at 0^0 C and t^0 C then, we have

$$R_t = R_0(1 + \alpha t)$$

where α is the temperature co-efficient of resistance for that substance, while in case of semi-conductors like germanium and silicon the resistance decreases with temperature.

Limitations of ohm's law:

(i) Only small current should be allowed to flow through the circuit so that temperature should remain constant.

(ii) The conductor should not be subjected to any kind of stress or tension.

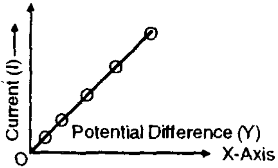


Fig.

Biot-Savart law: Biot and Savart gave an empirical formula to compute the magnetic field strength at any point due to a current flowing in the circuit of any shape. The magnetic field $\vec{dB}$ at any point P due to the current element is given by

$$\vec{dB} = \frac{\mu_0}{4\pi} \frac{I.\vec{dl} \times \vec{r}}{r^3}$$

where dl = current element of length dl of conductor AB.

I = current flowing through a conductor wire AB.

The magnitude of the field is given by

$dB = \frac{\mu_0}{4\pi} \frac{I.dl \sin\theta}{r^2}$ where θ is angle between the vector $\vec{dl}$ and position vector $\vec{r}$.

The direction of the magnetic field $\vec{dB}$ is the same as the direction of the vector $\vec{dl} \times \vec{r}$.

The direction of field $\vec{dB}$ may also be given from the analog y. According to right hand thumb rule, if we hold a wire carrying current in our right hand such

that the thumb points along the direction of current, the fingers will curl round the wire in the direction of magnetic field arround the wire.

Magnetic field at the centre of a circular coil: is given by the expression $B = \frac{\mu_0 I.n}{2r}$ tesla (or weber m^{-2} where r is the radius of a loop of wire in which current I is flowing, n is the number of turns of the coil.

Magnetic field along the axis of a circular coil: is given by the expression

$$B = \frac{\mu_0 n I r^2}{2\,(r^2 + x^2)^{3/2}} \text{ tesla}$$

Here a circular current loop of radius r carrying current I ampere held perpendicular to the plane of paper. The point P is situated on the axis of the coil at a distance x from the centre of the coil. The magnetic field at point P is as given above. Also n is the number of turns of the loop.

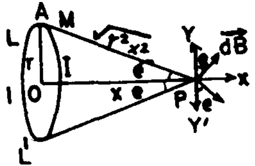


Fig.

Magnetic field at the centre of a long solenoid: A coil which is wound in a cylindrical shape is called a solenoid. If n be the number of turns per unit length, r be the radius of each turn and I be the current flowing through the solenoid. The magnetic field at the centre of a long solenoid is given by, $B = \mu_0 nI$.

Relation between electro-chemical equivalent and equivalent weights:

$\frac{Z_1}{Z_2} = \frac{E_1}{E_2}$ where Z_1 and Z_2 are the E.C.E. of two substances whose chemical equivalent are E_1 and E_2 respectively.

Seebeck effect (or thermoelectric effect): Seebeck found that when two different metal wires are joined at their ends to form a closed circuit and one of the ends (or junctions) is heated while the other is kept cold, an electric current is produced in the circuit. The current so produced is called ***thermoelectric current*** and the pair of metal wires as *thermocouple.*

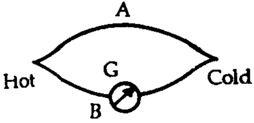


Fig.

Neutral and Inversion temperature: The temperature at which the thermo-electric current is maximum (270° for the Iron-coppor couple) is called *neutral temperature* and the temperature at which the

direction of the current is reversed is called the temperature of the inversion.

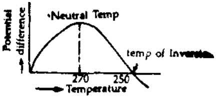


Fig.

Thermoelectric thermometer: is a sensitive instrument commonly used for measuring high temperatures. It is based

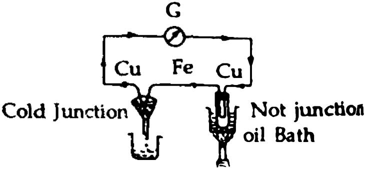


Fig.

upon the principle that for a given thermocouple value of thermo e.m.f. depends upon the temperature difference between cold hot junction.

Measurement of temperature: Before measuring unknown temperature a caliberation curve is plotted between temperature of hot junction and the deflection obtained in the galvanometer. Now the thermometer is brought in contact with the body whose temperature is to be determined and the reading of the galvanometer is read. The temperature corresponding to this value of the galvanometer reading is read from the caliberation curve.

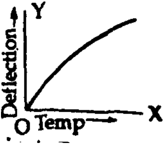


Fig.

Thermopile: It is a sensitive instrument used for detection of heat radiation and measurement of their intensity. It is based upon the thermoelectric effect.

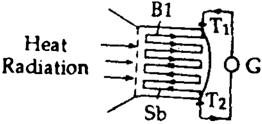


Fig.

Thermal radiations coming from the furnace are allowed to fall on the set of junctions. These radiations are absorbed and hence the temperature of all junctions of this set is raised. The other set of junctions remain cold. Due to difference in temp, thermo *e.m.f.* is set up in each thermocouple. As all the thermocouples are joined in series the e.m.f of individual couples are all added thus the resultant e.m.f. is large.

Conversion of galvanometer into ammeter: Galvanometer can be converted into ammeter by connecting a very low resistance (shunt resistance R_{sh}) in parallel with the galvanometer.

$$R_{sh} = \frac{I_g . R_g}{I - I_g}$$

Conversion of galvanometer into voltmeter: Galvanometer can be converted into voltmeter by connecting a very high resistance in series with galvanometer.

$$V = (R_g + r) . I_g$$

Moving coil galvanometer: Galvanometer. Instruments used for detecting and measuring electric currents are called galvanometers. A moving coil galvanometer is based on the principle that when a current carrying conductor is placed in a magnetic field, it experiences a mechanical forces whose direction is given by the Fleming's left hand rule.

Construction: It consists of a narrow coil

G having a large number of turns of a insulated wire on a light metallic frame. The coil is suspended between the pole pieces of a cylindrical magnetic *M* built up of permanently magnetised rings of hard steel.

One end of the coil is attached to a very fine spiral spring the lower end of which is connected to one of the terminal screws on the base board of the instrument. Thus, the current enters through the strip of *phosphorbronze*, and after passing through the coil, leaves through the spiral spring.

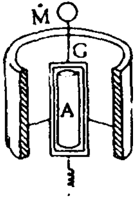


Fig.

A soft iron cylinder, called the core, is placed symmetrically between the pole pieces of the magnet. Besides, the pole pieces are given cylindrical shape, the iron core helps to concentrate the magnetic field so that the directions of the lines of force in the gap between the pole pieces and the soft iron core almost coincide with the radii of the cylindrical pole pieces.

Such a magnetic field is called radial magnetic field. It is clear that in such a field, the plane of the coil in all its positions is always parallel to the magnetic field.

Electronics: Electronics is that branch of science and engineering which deals with the electron flow through a vacuum or gas or semi-conductor is known as **electronics**.

Electronic devices: The instruments which use elec·rons for useful purposes are called electronic devices.

Essentials of an electronic device:

(i) Some source of electrons

(ii) Suitable arrangement for manipulating them. This mean an arrangement to alter their velocities; alter their direction as well as number etc.

(iii) Some arrangement for observing these effects produced by our manipulation. It may be a fluorescent screen as in television and radar.

Electron emission: When the energy is imparted to the electrons from some external source they leave the surface of the metal and this phenomenon is called electron emission in metals.

Work function: The minimum energy which the electron should have in order to escape from the surface of the given material and may not be pulled back by the remaining positively charged atom is called the work function which depends upon the nature of the material.

Thermionic emission: The process of the escape of electrons from the surface of

metal when heated suitably is called the thermionic emission.

Thermionic emitter: The substance used for electron emission is known as an emitter or cathode. A cathode should have the following properties:

(i) It should have low work function

(ii) It should have high melting point

(iii) It should have high mechanical strength.

Commonly used thermonic emitters

Emitter	Work function	*Operating Temp.*	*Emission efficiency*
Tungsten	4.52 eV	2327° C	4 mA/watt
Thoriated tungsten	2.63 eV	1700° C	60 mA/ watt
Oxide-coated	1.1 eV	750° C	200 mA/ watt

Types of cathode

(i) *Directly heated cathode.* When current is passed into the filament *F*, it becomes hot and emits electrons.

(ii) *Indirectly heated cathode.* The current is passed into filament *F*. It get hot and then heats the cathode C lying near it.

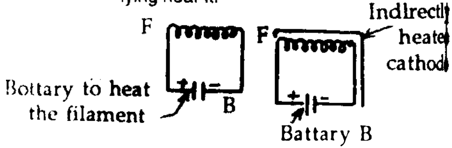


Fig.

Field emission: The process of electron emission by the application of strong electric field at the surface of a metal is known as field emission.

Vacuum tube: An electric device in which the flow of electrons is through a Vacuum is known as a vacuum tube.

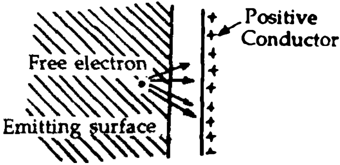


Fig.

Vacuum diode: the word diode means electrodes. A diode consists of two electrodes, a cathode C and an anode or plate *P*. The cathode (along with its heating element) and the plate are fixed inside a glass tube T. The air from the glass tube is removed and then its is sealed.

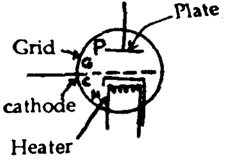
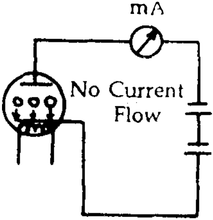


Fig.

Space charge: The cloud of negatively charged electrons near the cathode is called space charge.

Working of a diode: When a plate P is positively charged, it attracts electrons



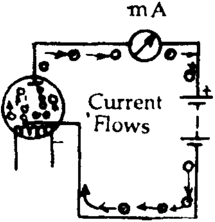
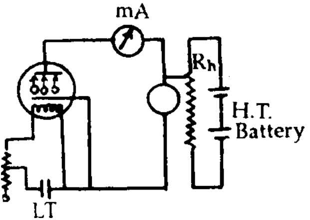


Fig.

emitted by cathode and current flows through the diode as shown in Fig. (*a*). When the plate is negatively charged it repels the electrons emitted by cathode; due to which no current flows through the diode.

Diode characteristics: When cathode is kept at a constant temperature T_1 and a+ve potential is applied on anode, the plate current increases along the curve *OA*. The portion *OA* if known as space charge limited region. As we increase the plate potential for a certain value of plate voltage, the number of emitted electrons is equal to number of collected electrons by the plate. Now the plate current is saturated and this condition is shown at D on anode characteristics. Now, we increase furtherplate voltage but there is no increase in plate currents. If cathode temperature is increased from T_1 to T_2 the value of saturation current increases as shown in fig.


mA
Rh
H.T.
Battery
LT

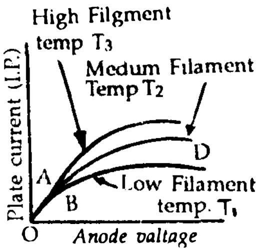

High Filgment
temp T3
Medum Filament
Temp T2
D
A
Low Filament
temp. T1
B
Plate current (I.P.)
O
Anode valtage

Fig.

Rectifier: A device which converts an alternating current into a direct current is known as rectifier.

Rectification: The process of converting an alternating current into a direct current is called rectification.

Diode valve as half wave rectifier: AC input is connected across the primary of a transformer. During the first half cycle, when *A* is +ve, the plate attracts electrons and current flows through the load. During second half-cycle *P* is nega-

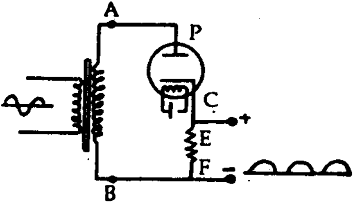


Fig.

tive with respect to the cathode and no electron reach the plate. Therefore no current flows in the second half cycle through the load. E acts as a +ve terminal while *F* acts as -ve terminal.

Diode valve as full wave rectifier: Here we make use of two diodes *AC* source is connected to the primary of a transformer. The secondary of the transformer is centre tapped at point *D*. During the first half-cycle, when A is +ve w.r.t. *B*, the

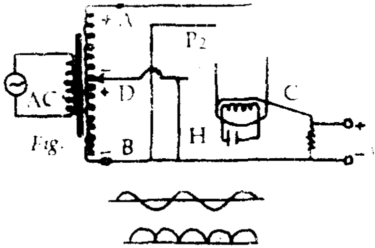


Fig.

Fig.

+Ve potential acts on the plate of diode 1. The electrons are attracted and current flows. The current does not flows through diode 2, because its plate P_2 is negative with respect to its cathode. During second half cycle *B* is +ve and *A* is -ve and a -ve potential acts on the plate of diode 2. The current flows via the diode 2. No current flows through diode. 1. The full wave of *AC* is rectified and this is known as full wave rectification.

Triode: A triode consists of three electrodes; a plate *P*, a cathode (C) and a grid (G). There is also a heating fila-

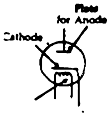


Fig.

ment H placed inside the cathode. Cathode The three electrodes are enclosed in an evacuated glass tube. The bottom of the glass tube is fitted into a bakelite base and there are five metal pins fixed in this base. These pins are for making the connections of the triode with external circuit.

Action of grid: Since the grid is nearer to the cathode than the plate, a potential placed on the grid has a much larger effect on the plate current than the same potential placed on the plate. The grid has a controlling effect on the flow of plate current and is usually called a control grid.

Cut off bias in a triode: The smallest negative grid voltage capable of cutting off (*i.e.*, making the plate current zero) the plate current is called the cut off bias.

Constants or parameters of a triode:

Amplification factor (μ). It is the ratio of the change in plate potential to the change in grid potential provided the

change in plate current is the same in both the cases.

$$\mu = \left[\frac{\Delta E_v}{\Delta E_g} \right] I_p$$

Mutual conductance (gm): It is the ratio of the change in the plate current to the change in grid potential provided the plate potential is constant.

$$g_m = \left[\frac{\Delta I_v}{\Delta E_g} \right] E_p$$

Plate resistance: It is the ratio of the change in plate potential to the change in plate current provided the grid potential is constant.

$$T_r = \left[\frac{\Delta E_v}{\Delta I_p} \right] E_g$$

Relation between the three constants

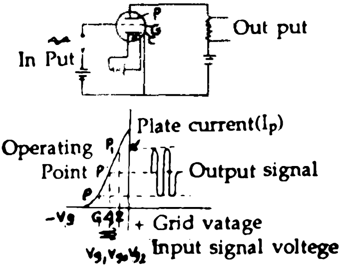
$$\mu = r_v \times gm$$

Amplification factor = plate resistance × mutual conductance

Amplifier: An amplifier is a device to increase the amplitude of the input signal.

Triode as an amplifier: The amplification by the triode is based upon the fact that a small change in grid potential produces a large change is the plate current.

When the gride is given a steady **voltage** *Vso* by grid bias, a steady current appears across the load resistance *R*. When an input A.C. signal (e_g) is applied to the grid, the effective voltage between



Fig

grid and the cathode swings V_{g1} to V_{g2} along its meanless bias level V_gO. The variations in grid cathode voltage cause a pulsation in plate current and a large plate alternating voltage corresponding to the input signal appears across the load resistance R.

P-N Junction: When a *p*-type semiconductor is suitably joint of *n*-type semiconductor, the contact surface is called **pn-junction.**

Formation of PN junction: A junction diode or *P-N* junction is an arrangement obtained by growing single crystal of either *Ge* or *Si* which at first contains impurities of either P or N-type. In the middle of the growth process, the impurities of the opposite kind are added to the melt, so that the remainder of the crystal abruptly grows into the opposite type.

Potential barrier at the junction: Due to the high concentration, so free electrons in the N-type diffuse through the junction

to the P-region and likewise some holes in the P-type diffuse into the N-region. Transfer of these changes to either region disturbs the neutrality of that region making P-region negative and N-region positive. This results in the establishment of an electric field at the junction as if a fictitious battery B_1 were con-

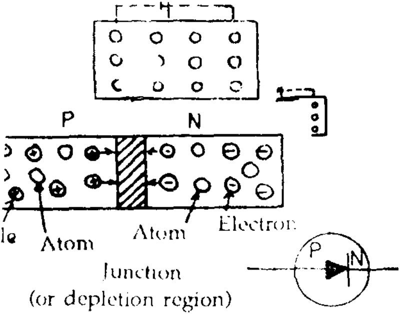


Fig.

nected with its positive terminal to N-type and negative terminal to P-type. This potential produced is called potential barrier. This barrier opposes any further movement of charges through the junction. The thickness of the depletion region is of the order of 10^{-6}m.

Applying voltage across pn junction: A potential differences across pn junction

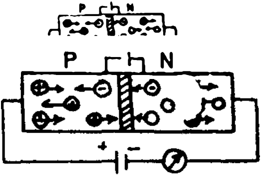


Fig.

can be applied in two ways namely; *forward biasing and reverse biasing.*

Forward biasing: When external voltage applied to the junction is in such a direction that it cancels the potential barrier, thus permitting the current flow it is called **forward biasing.** Inforward bias the positive terminal of the battery is connected to the P-type side of the crystal and the negative terminal to its N-type side. The battery voltage will oppose the barrier voltage. If exceed the barrier voltage, the free electrons in N-type and holes in P-type will migrate from one end of the crystal across the junction to the other end.

Reverse bias: If the negative terminal of the battery be connected to the *P*-type portion and positive terminal to the *N*-type portion as shown in Fig. The crystal is said to be given reverse bias. The holes (the majority carrier in *P*-type) and electrons (the majority carries in *N*-type) moves away from the junction thereby

increasing the thickness of the junction. But some thermally generated holes and electrons do cross the junction and a feeble current flows through the junction.

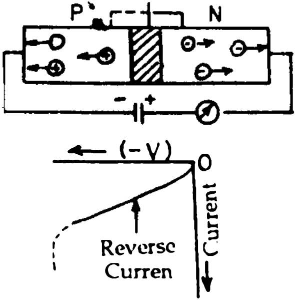
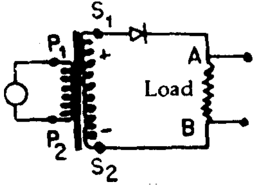


Fig.

PN-junction diode as a rectifier:

(a) **Half wave rectifier.** The circuit for a half wave rectifier using Pn diode transistor 's shown in fig. (*i*) Here *D* is the *PN* diode

transistor. R is the load and P_1 P_2 and S_1 S_2 are the primary and secondary terminals of a transformer. During the first half cycle, when S_1 is +ve with respect to



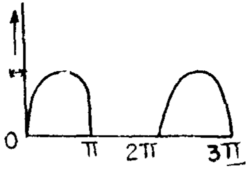


Fig.

S_2 there is a flow of current in the direction as shown in fig.

(ii) The point A is +ve and B is -ve. In second half cycle when S_1 is -ve with respect to S_2 so no current flows in the circuit. The process is repeated and across the load half wave rectified DC is obtained as output.

(b) ***Full-wave rectifier:*** The circuit for a full wave rectifier using PN diodes D_1 and D_2 is shown in fig. R is the load and P_1 P_2 and S_1 S_2 are the primary and secondary terminals of a transformer. During the first half input cycle S_1 is +ve and S_2 is -ve with respect to E. current flows through the diode D_1 and not through D_2. During the second half cycle S_1 is -ve and S_2 is +ve with respect to E. Current flows through diode D_2 and not through D_1. During both the half cycles. A is +ve and B is -ve. The process is repeated and across the load a full wave rectified D.C. is obtained.

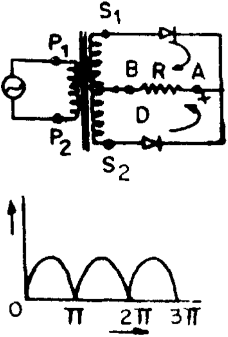
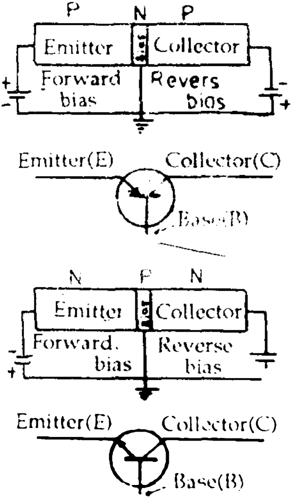


Fig.

Junction transistor: A transistor is an arrangement obtained by growing a narrow section of either *N*-type crystal between two relatively wide sections of *p*-type (called *PNP* transistor) or growing *p*-type crystal between two wide sections of *N*-type, (called *NPN* transistor).



P
N
P
Emitter
Collector
Forward
bias
Revers
bios
Emitter(E)
Collector(C)
Base(B)
N
P
N
Emitter
Collector
Forward.
bias
Reverse
bias
Emitter(E)
Collector(C)
Base(B)

Fig.

Emitter: The section on one side that supplies charge carriers (electrons or holes) is called emitter. The emitter is always forward biased w.r.t. base so that it can supply a large number of majority carrier.

Base: The middle section which forms two *pn* junctions between the emitter and collector is called the base.

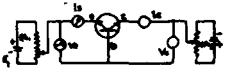
Collector: The section on the other side that collects the charge is called the *collector* The collector is always *reverse biased.*

Common base amplifier: In this circuit, the base is common to both the emitter and the collector circuits. The input is applied to the emitter base circuit and output is taken between collector and base.

Characteristic of common base transistor: The complete electrical behaviour of a transistor can be described by stating the interelation of the various currents and voltage. These relationships can be conveniently displayed graphically and

the curves obtained are known as characteristic curves. There are three types of characteristics of common base.

(1) *Emitter (or Input) characteristics:* A graph showing the relationship between the emitter voltage and the emitter current at constant collector voltage is called the emitter (or input) characteristics. The characteristic curves reveal the following facts:



(i)

Fig.

(i) For a given value of V_c, the emitter current I_c increases rapidly with the increase in V_c.

(ii) the emitter current I_c rises more rapidly as V_c is made more negative. The reason is that small negative increase in V_c causes larger number of holes get attracted by the collector.

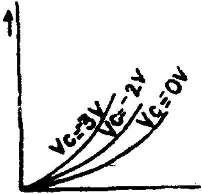


Fig.

(2) ***Output characteristics*** : *It is a curve between collector current I_c and collector base voltage V_c at constant emitter current I_c.* The characteristics reveals the following facts:

(i) For any value of the emitter current, the collector current does not become zero when collector voltage is zero, A small positive voltage (*OA*, *OB OC*) is to be applied to collector in order to reduce the collector current to zero. This means that holes due to their high concentration continue flowing from emitter into the collector inspite of small opposing collector voltage.

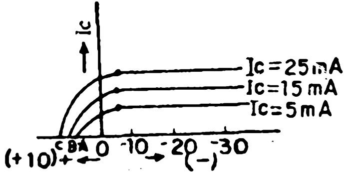


Fig.

(ii) After *D*, *E* and *F* the curves are almost horizontal. This indicates that there is no increase in I_c after *D*, *E*, *F*. This is

saturation and collector resistance is high in this region.

(iii) As the collector voltage is made more and more negative, collector current increases (the portion *AD, BE, CF* etc.). This indicates the collector resistance is low in this region.

Transfer characteristics: The characteristic curve which represents the variation of the collector I_c with the emitter I_c for a fixed collector voltage V_c for common base transistor in a straight line and is known as transfer characteristic curve.

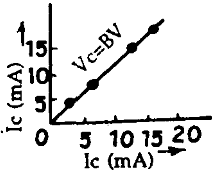


Fig.

Common emitter amplifier: The common emitter *npn* amplifier circuit. Note a battery V_{bb} is connected in the input circuit in addition to the signal voltage. During the +ve half-cycle of the signal the forward bias across the emitter-base junction is increased. Therefore more electrons flow from the emitter to the collector via the base

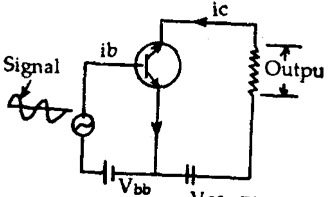


Fig.

Fig.

This causes an increase in collector current. The increased collector current produces a greater voltage drop across

the collector load resistance R_c. However during the negative half cycle of the signal, the forward bias across the emitter and base junction is decreased. Therefore, collector current decreases. This results in the decreased out put voltage (in the opposite direction). Hence an amplified out put is obtained across the load.

Base current amplification factor (β). The ratio of change in collector current (ΔI_c) to the change in base current (ΔI_B) is known as *base current amplification factor*

i.e
$$\beta = \frac{\Delta I_c}{\Delta I_B}$$

Relation between α and β, $\beta = \dfrac{\alpha}{I - \alpha}$

Characteristics of common emitter transistor: Figure shows the circuit diagram for determining the characteristics for a common emitter *npn* transistor circuit.

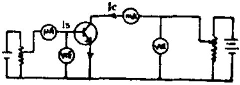


Fig.

Input characteristics: It is a curve between base current I_B and base emitter voltage V_{VE} at constant collector emitter voltage V_cC

Important points to be noted from the characteristics:

(i) The characteristics resembles that of a forward biased diode curve. This is expected since the base-emitter section of transistor is a diode and it is forward biased.

(*ii*) As compared to *CB* arrangement, *Is* increased less rapidly with V_{BE}. therefore, input resistance of *CE* circuit is higher than that of *CB* circuit.

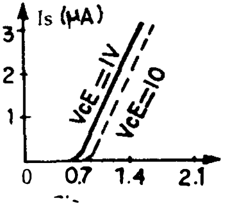


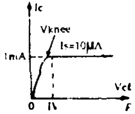
Fig.

Input resistance: $r_1 = \frac{\Delta V_{BE}}{\Delta I_B}$

at constant V_{CE}.

It is the curve between collector current I_C and collector-emitter voltage V_{CE} at constant current I_B.

The collector current I_C varies with V_{CE} for V_{CE} between O and 1 V only. After this, collectorcurrent an independence of V_{CE}. This value of V_{CE} upto which collector current I_C changes is called the knee



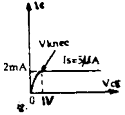


Fig.

voltage (V_{knee}). The transistors are always operated in the region above knee voltage.

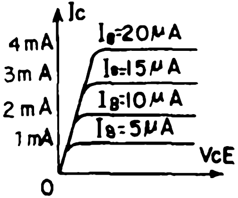


Fig.

Above knee voltage, O_C with increasing V_{CE} is caused by the collector depletion layer getting wider and capturing a few more majority carrier before electron-hole combination occurs in the base area.

For any value of V_{CE} above knee voltage, the collector current I_C is approximately equal to $\beta \times I_B$.

Output resistance: It is the ratio of change in collector emitter voltage (ΔV_{CE}) to the change in collector current (ΔI_c) at constant I_B.

Output resistance, $r_0 = \dfrac{\Delta V_{CE}}{\Delta I_c}$

Common collector amplifier: In this arrangement, input is applied between the base and collector while output is taken from the emitter. Here collector of the transistor is common to both input and output circuits and hence the name is common collector.

Current amplification factor (γ): The ratio of change in emitter current (ΔI_E) to the change in base current (ΔI_B) is known as current amplification factor in common collector (c.c) arrangement *i.e.*,

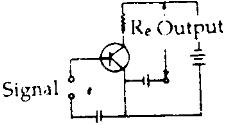


Fig.

$$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

Relation between γ and α, $\gamma = \dfrac{1}{1-\alpha}$

Current gain (or current amplification factor): (i) It is defined as the ratio of small change in the collector current to the small change in the emitter current at constant collector voltage.

$$\alpha = \left(\frac{\delta I_c}{\delta I_c}\right) V_c \; (V_c \text{ is constant})$$

(ii) ***Input resistance:*** It is defined as the ratio of change in emitter base voltage to the emitter current.

$$\text{Input resistance} = \frac{\delta V_c}{\delta I_c}$$

(iii) ***Output resistance:*** It is defined as the ratio between the change in collector base voltage and the change in collector current.

$$\text{Output resistance} = \frac{\delta V}{\delta I_c}$$

It is very high (= $10^5 \Omega$).).

(iv) ***Resistance gain:*** It is defined as the ratio of output resistance to the input resistance.

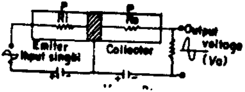


Fig.

$$\text{Resistance gain} = \frac{\text{Output resistance}}{\text{Input resistance}}$$

(v) ***Voltage gain*** $= \dfrac{V_0}{V_i} = \alpha \dfrac{R_L}{R_i}$

i.e, Voltage gain = Current gain

$$\times \frac{\text{Load resistance}}{\text{Input resistance}}$$

(vi) ***Power gain:*** It is defined as the ratio

of output power to the input power.

Power gain = Current gain × voltage gain.

Oscillator: An electronic device which produces undamped electrical oscillations of very high frequency is called an oscillator. A circuit consisting of inductance L_1 in parallel with a capacitor C_1 oscillates with frequency f given by

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

But these oscillations are damped due to power loss in the resistance associated with the inductance. For maintain the oscillation in L_1-C_1 circuit it is essential to supply the energy in proper phase so as to meet the losses.

The feedback coil L_2 in the base circuit is magnetically coupled to the tank circuit coil, L_1. In practice L_1 and L_2 form the primary and secondary of the transformer. When the switch S is closed, collector current starts increasing and charges the capacitor C_1. When this

capacitor is fully charged, it discharges through L_1, setting up oscillations of frequency determined by expression given above. These oscillation induce some voltage in coil L_2 by mutual inductance. The frequency of voltage in coil L_2 is the same as that of the tank circuit. The voltage across L_2 is applied between the base and emitter and appears in the amplified form in the collector circuit, thus overcoming the losses occurring in the tank circuit. The phase of feedback must

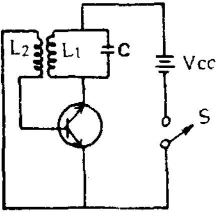


Fig.

be correct *i.e.*, energy supplied to the tank circuit is in phase with generated oscillations.

A phase shift of 180° is created between the voltages of L_1 and L_2 due to transformer action. A further phase shift of 180° takes place between base emitter and collector circuit due to transistor property. The energy of feedback to the tank circuit in phase (180° + 180° = 360°).

Modulation: In order to make speech or music (called audio frequency signal) to be heard over long distances, the audio frequency signal is superimposed over a very high radio frequency signal (i.e., a carrier wave). The process of superim-

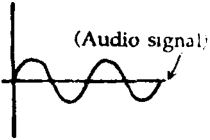


Fig.

posing audio frequency signals on radio frequency signals is called **modulation.** The modulated R.F. wave is transmitted from radio station. These waves reach the receiver antenna of a radio or transistor

Demodulation: The process of recovering the audio signal from the modulated wave is known as **demodulation or detection.**

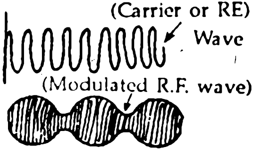


Fig.

Diode as detector: A simple detector circuit employs a vacuum diode and filter circuit. The modulated wave of desired frequency is selected by parallel tuned circuit L_1 C_1 and is applied to the vacuum

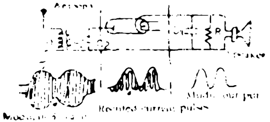


Fig.

diode During +ve half cycles of modulated wave, the diode conducts while during -ve half cycles it does not. The rectified modulated wave contains radio frequency and the audio signal. The r.f. wave is filtered by the capacitor C shunted across the speaker. The value of this capacitor is sufficiently large to present low reactance to r.f. component while presenting a high reactance to the

audio signal. The result is that the r.f. component is by-passed by a capacitor C and the signal is passed on to the speaker for sound reproduction.

Cathode ray oscilloscope (C.R.O.) : Cathode ray oscilloscope is useful in determining the wave form and nature of current and voltage precisely. This is

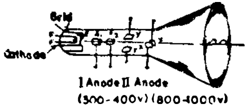


Fig.

commonly employed as a display screen for television, computers etc. It consists of an electron gun comprising of a filament F, a gird G and anode A_1, A_2. The electron beam coming out of the electron

gun can be deflected by electric field applied on plates *YY* and *XX*. In cathode ray oscilloscope signal (which is to be investigated) is fed on *YY* plates and a saw tooth wave is given on *XX* plates. The frequency of the saw tooth wave is varied in such a way that its frequency is synchronised with the frequency of the signals. Therefore a stationary picture of wave is formed on a screen coated with flourscence material.

MAGNETISM

Magnetic Poles: These are the regions in the body of a magnet where the power of attracting iron filings is found to be maximum.

In every magnet there are two poles i.e. south pole and north pole.

Magnetic axis: It is the line joining the two poles of a magnet inside its body.

Magnetic meridian: It is that vertical plane which passes through the magnetic axis of a freely suspended magnet.

Magnetic length: The poles of a magnet are not usually located at its ends, but slightly inside the body. The distance between the poles is called magnetic length.

Magnetic substances: The substances which are susceptible to magnetic in-

fluence are called magnetic substances. e.g. iron, steel, nickel etc.

Magnetic equator: A line perpendicular to magnetic axis and passing through the middle point of the magnet is called equatorial line or magnetic equator.

Coulomb's law of force: The force of attraction or repulsion F, between two like or unlike poles of strength, m_1, m_2 C.G.S. units placed at a distance 'd' apart is given by

$$F = \frac{m_1 m_2}{\mu d^2}$$

where μ = constant known as permeability of the medium.

For air, μ = 1 C.G.S. units.

Unit Magnetic Pole: In electromagnetic C.G.S. system a unit magnetic pole is that pole which when placed in air (vacuum) at a distance of 1 cm from an equal and similar pole repels it with a force of 1 dyne.

Field Strength of Magnetic Intensity: At a point in the magnetic field, it is the force experienced by a unit north pole placed at that point, provided and north unit pole does not change the field

Unit of magnetic intensity - **Oersted.**

The intensity at a point is one oersted if a unit north pole at placed that point experiences a force of 1 dyne.

Magnetic Moment *(M):* of a magnet is defined as the moment of a couple acting on it when placed perpendicular to uniform magnetic field of unit intensity. Numerically

$$M = m \times 2l$$

where

m = pole strength.

$2l$ = effective length of magnet.

The couple, C: action on a magnet placed in a uniform magnetic field of intensity H is given by

$$C = M H \sin \theta$$

where

θ = angle made by the magnet with the field.

Magnetic Intensity (**Ha**) due to a bar magnet at **a** point on the **axial** line (**end on position**) is given by

$$H_a = \frac{2.M.d}{(d^2 - l^2)^2}$$

where M = magnetic moment of magnet

d = distance of the point from the centre of the magnet.

$2d$ = effective length of magnet.

If l is very small as compared to d, then

$$H_a = \frac{2m}{d^3}$$

Magnetic Intensity (He) at a point on the equatorial line (**Broad side on position)** is given by

$$H_e = \frac{M}{(d^2 + l^2)^{3/2}}$$

where d = distance of the point from the centre of magnet.

$2l$ = effective length of magnet.

If l is very small as compared to d, then

$$H_e = \frac{M}{d^3}$$

Intensity (H) at a point P due to a short bar magnet

It is given by $H = \frac{M}{r^3}\sqrt{3\cos^2\theta + 1}$

where r = distance of the point P from the centre of magnet.

θ = angle made by the line joining point P and mid point O of the magnet with magnetic axis of the magnet.

Work done in deflecting a magnet in a uniform field

Work done (W) in deflecting a magnet of magnetic moment M through an angle θ in a uniform magnetic field of strength H is given by $W = MH(1 - \cos\theta)$

Magnetic Potential

Magnetic potential at a point in a magnetic field is numerically equal to the work done in ergs in bringing a unit north pole from infinity to that point against the direction of the field. The magnetic potential, V, at any point due to a single pole strength m is given by

$$V = \pm \frac{m}{d}$$

where d = distance of the point from the single pole.

V is positive for north pole and V is negative for south pole.

Magnetic shell: It is a thin sheet of magnetic material of any shape which is so magnetised that one face shows north pola-rity and the other face shows south polarity.

It can also be defined as a thin sheet of magnetic material, magnetised at every point in a direction normal to shell.

The strength of the magnetic shell (ϕ at any point is *the product of intensity of* magnetisation (I) [i.e. magnetic moment per unit volume] and the thickness (t) of the shell.

$$\phi = I \times t$$

Magnetic Potential due to a Magnetic shell: Magnetic potential (V) due to a magnetic shell at a point is numerically equal to the product of the strength of magnetic shell (ϕ) and the solid angle (Ω) subtended by the boundary of the shell at that point. $V = \phi.\Omega$

For a closed shell the potential at a point inside it will be equal to $4p\phi$ and at a point outside it will be zero.

Magnetic Elements of Earth's Field

Declination (θ)***:*** The declination θ at a place is the angle between the geographical meridian and magnetic meridian at that place.

Dip, (Inclination), ϕ***:*** The dip at a place is the angle which the earth's field makes

with earth's surface at the place.

Horizontal component of Earth's Field (H): At a given place, H, is the component of total intensity of the earth's magnetic field, I, along the horizontal in the magnetic meridian at that place. The total intensity, I, of the earth's magnetic field can be resolved into two components, one vertical(V) and the other horizontal (H)

$V = I \sin \phi$

$H = I \cos \phi$

$V/H = \tan \phi$

$V^2 + H^2 = I^2$

Dip Circle: It is an instrument that is used to determine the magnetic dip at a place. The value of dip increases suddenly when we approach a locality of iron ore.

Isogonic lines: These are the lines which join places of equal declination.

Agonic line: This is the line of zero declination.

Isoclinic lines: These are the lines which

join the places of equal dip or inclination.

Aclinic line: is the line joining places of zero dip. This line is also known as **magnetic equator** and goes nearly side by side with geographical equator.

Isodynamic lines: are lines joining places of equal H, the horizontal component of earth's magnetic field.

H is **zero** only at two poles where the magnetic needle remains perfectly vertical.

Note: The magnetic elements (θ, ϕ and H) at a place are not fixed (constant) permanently. They are found to change regularly as well as abruptly. The changes are classified as follows:

(i) Diurnal changes (ii) Annual changes. (iii) Secular changes (iv) Abrupt changes.

Relation between magnetic elements: If R is the total magnetic intensity along OC and θ is the angle of dip (see fig.) The H = R cosθ along OA and the vertical component

$$V = R \sin \theta \text{ along OB.}$$

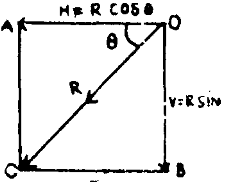


Fig.

$\therefore R^2 = V^2 + H^2$ i.e. $R = \sqrt{V^2 + H^2}$

and $\tan\theta = \dfrac{V}{H}$

Magnetic and Non-magnetic substances: Those substances which on being placed in a magnetic field get attracted by magnet are known as magnetic substances i.e. Fe, Co, Ni. Those substances which on being placed in a magnetic field are not attracted by magnet are called non-magnetic substances.

Classification of Magnetic substances

They are classified as:-

(i) Diamagnetic substances

(ii) Paramagnetic substances.

(iii) Ferro-magnetic substances.

Diamagnetic substances are those substances which on being placed in a magnetic field get feebly magnetised in direction opposite to that of the magnetising field. Such substances get repelled when brought near a strong magnet. This property of diamagnetic substances is known as **diamagnetism**.

Examples of diamagnetic substances:

Bismuth (Bi), Hydrogen (H_2), Nitrogen (N_2), Water (H_2O), Common salt (NaCl), Diamond (C), Gold (Au), Silver (Ag), Copper (Cu), Zinc (Zn), Mercury (Hg) etc.

Paramagnetic substances are those substances which on being placed in a magnetic field get feebly magnetised in the direction of the magnetic field.

Such substances, get attracted towards the magnet, when brought near a strong magnet. This property of paramagnetic substances is called **paramagnetism**.

Examples of Paramagnetic substances

Aluminium (Al), Sodium (Na), Platinum (Pt), Maganese (Mn), Copper (II) chloride ($CuCl_2$), Oxygen (O_2) etc.

Ferromagnetic substances are those which on being placed in a magnetic field get strongly magnetised in the direction of the magnetic field.

Ferromagnetic substances when brought near the magnet get very much attracted towards the magnet. This property of ferromagnetic substances is known as **ferromagnetism.**

Examples of Ferromagnetic substances

Iron (Fe), Nickel (Ni), Cobalt (Co), Magnetite (Fe_3O_4) etc.

Some properties of Magnetic Substances Permeability when a magnetic substance is placed in a uniform magnetic field (where lines of force are parallel) number of lines of force are seen to be crowed through the substance. The conducting power of the substance for the lines of force

is called permeability. It is taken as unity for air. $B = \mu.H$.

Susceptibility: If a bar of iron is placed in a magnetic field, it gets magnetised and pole strength or magnetisation depends upon the strength of magnetic field. Thus if H is the magnetic field and σ is the resulting intensity of magnetisation then $\sigma/H = k$ is the susceptibility of the specimen. The value of k (susceptibility) and μ (permeability) are high for ferromagnetic substances.

(k) Susceptibility is inversely proportional to its absolute temperature.

$$k \alpha \frac{1}{T}$$

This is known as **Curie's Law.** This law holds good upto a temperature known as **curie temperature.**

The value of permeability is more than unity ($\mu > 1$) for para magnetic substances. For such substances susceptibility (k) has small positive values.

For diamagnetic substances ($\mu < 1$) and (k has negative values)

Relation between magnetic susceptibility and Permeability

$$k = \frac{\mu - 1}{4\pi}$$

Rules for Polarity of Magnetism in a coil carrying a current

(i) *End Rule:* When looking at the end of the bar if the current is seen in the coil in anticlock wise motion, the end will be north pole.

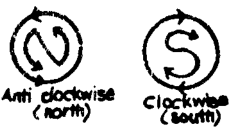


Fig.

Hand Rule: Hold the thumb of right hand at right angles to the fingers. Place the hand on wires with the palm facing the bar and

fingers pointing in the direction of current, the thumb will point towards the north pole of the bar.

(iii) ***Ampere's Rule:*** Imagine a man swimming in the circuit in the direction of the current, with his face towards the bar, then his left hand will point towards north pole of the magnet.

Magnetic Flux: It is given by

$$\phi = \vec{B}.\vec{A}$$

where

A = area of surface.

unit of magnetic flux (ϕ) is **weber**.

Weber: One weber is the magnetic flux linked with a surface of magnetic field one Tesla over an area of $1 m^2$

$$\therefore \quad 1 wb = 1 Tm^2$$

Tesla or 1 amper-metre is the S.I. unit of magnetic intensity (H)

$$H = \frac{B}{\mu} = \frac{m}{4\pi d^2}$$

Tesla: One tesla is the magnetic field acting

at a point if one coulomb charge moving with 1m/s velocity through that point at right angles to the field experiences a force of 1 Newton.

Tangent Law: When a freely suspended magnet is acted upon by two uniform magnetic fields of strength F and H at right angles to each other, the magnet comes to rest in a certain position making an angle with H. In this position the moment of couple due to the field H is equal and opposite to the moment of couple due to field F. So

$$F = H \tan \theta$$

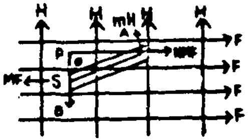


Fig.

Deflection Magnetometer

(i) **End on position on Tan A or Gauss A Position**

$$\tan\theta = \frac{2Mr}{H(r^2 - l^2)^2}$$

(ii) **Broad-side on position, or Tan B or Gauss B Position**

$$\tan\theta = \frac{M}{H(r^2 + l^2)^{3/2}}$$

Vibration Magnetometer: The period of oscillation (t) of a freely suspended magnet in a field of strength H is given by

$$t = 2\pi\frac{\sqrt{I}}{MH}$$

where

I = moment of interia of oscillating magnet

and $$I = \frac{(\text{length})^2 + (\text{breadth})^2}{12}$$

NUCLEAR PHYSICS

Composition of nucleus: The nucleus of an atom is composed of proton and neutrons whose mass are respectively.

$m_p = 1.673 \times 10^{-27}$ kg = 1.007277 a.m.u.

$m_n = 1.675 \times 10^{-27}$ kg = 1.008665 a.m.u.

The proton has a charge of +ve where $e = 1.6 \times 10^{-19}$ C and neutron is uncharged. Proton and neutrons are jointly called nucleons. The nucleus forms are *small central hard core* of an atom. It thus carries a positive charge. The electrons revolve around it in circular orbits. The positive charge on the nucleus is equal to the total negative charge of all the electrons. Almost the whole mass of an atom is concentrated in the nucleus, be-

cause total mass of electrons is negligible. The dimensions of nucleus are much small. The radius is estimated to be about 10^{-5} of the radius of the atom.

Atomic number (Z): The number of protons (or the number of electrons) is called the atomic number (Z) of the atom.

Atomic mass number (A): The total number of nucleous (*i.e.*, sum of number of protons and number of neutrons) is called the mass number (A) of the atom.

Isotopes: The atom of an element having the same atomic number (Z) but different mass number (A) are called isotopes. For example, hydrogen has three isotopes.

1. Hydrogen $_1H^1$ consists of 1 proton and no neutron.
2. Deuterium $_1H^2$ has 1 proton and 1 neutron.
3. Tritium $_1H^3$ contains 1 proton and 2 neutrons.

Chlorine has two isotopes $_{17}Cl^{35}$, $_{17}Cl^{37}$.

Isobars: Nuclei on atoms of different ele-

ments which have the same mass number but different atomic number are called isobars. For example ${}_{20}Ca^{40}$ and ${}_{18}Ar^{40}$ are isobars. They have entirely different chemical and physical properties. Similarly, ${}_{27}Co^{59}$ and ${}_{28}Co^{59}$ are also isobars.

Bainbridge mass spectrograph: Bainbridge mass spectrograph is modern spectrograph to analyse the presence of isotopes present in a sample. It is based on the principle that the deflection of any individual ion in magnetic and electric field depends on the ratio of its mass to electric charge. This consists of positive ions from a source is allowed to pass through a tube T with slits S_1 and S_2 at each end. When ions enter the tube through slit S_1, they are subjected to electric field and magnetic field. These fields are applied in such a way that electric field deflects the ions from left to right, while the magnetic field B' defects the ion in opposite direc-

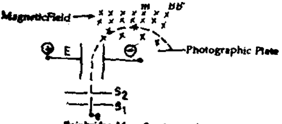
tion. Hence the ion experience two forces which are in equilibrium, then $B'ev = Ee$

$$\text{or} \qquad v = \frac{E}{B} \qquad \ldots(1)$$

The radius r of the inflected ion is given by

$$\frac{mv^2}{r} = Bev \qquad \ldots(2)$$

From equation (1) and (2) $\frac{e}{m} = \frac{E}{BB'} \times \frac{1}{r}$



Bainbridge Mass Spectrograph

Fig.

Electron volt (eV): It is defined as the energy acquired by an electron when it is

accelerated through a potential difference of 1 volt

$$1\ eV = (1.602 \times 10^{-19}\ \text{coulomb}) \times (1\ \text{volt})$$

$$1\ eV = 1.602 \times 10^{-19}\ \text{joule}$$

$$1\ MeV = 10^{6}\ eV = 1.602 \times 10^{-13}\ J.$$

Atomic mass unit (a.m.u.): Atomic mass unit is taken to be 1/12th of the actual mass of carbon isotope ${}_6C^{12}$.

$$1\ a.m.u. = 1.66 \times 10^{-27}\ kg$$

$$1\ a.m.u. = 931 \times 10^{6}\ eV = 931\ MeV.$$

Binding energy of the nucleus: is defined as the energy required to decompose a nucleus into its constituent nucleons and place them at rest at infinite distance from one another to avoid their chances of recombination.

Density of Nucleus:

Since volume of nucleus $= V = \frac{4}{3}\pi R_0^3 A$

$$= 7.24 \times 10^{-45}\ Am^3$$

So its density will be

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Mass of nucleus of mass number

$$A = M(\text{let})$$

or $$M = A \text{ a.m.u.}$$

$$= 1.66 \times 10^{-27} \text{ A kg}$$

Thus $$D = \frac{1.66 \times 10^{-27} \text{ A}}{7.24 \times 10^{-45} \text{A}}$$

$$= 2.293 \times 10^{17} \times \text{Kg/m}^3$$

The density of nuclei is independent of its mass number, all the nuclei have approximately same density.

Mass defect: The difference between the actual mass of the nucleus and the sum of the masses of the constituent nucleons is called **mass defect.** Thus energy equivalent to mass defect is the measure of the binding energy of the nucleus.

Average binding energy per nucleon: Dividing the binding energy of nucleus by the number of its nucleons we get

average binding energy per nucleon.

Binding energy: The protons and neutrons are held together within the nucleus by strong nuclear forces. Now if we want to disrupt the nucleons, some energy has to be applied. This energy is called binding energy and is defined as the energy required to decompose the nucleus into its constituents nucleons.

The mass of nuclei is less than the sum of masses of nucleons. This mass difference is called mass defect. The energy equivalent to this mass defect is called binding energy.

Binding energy per nucleon: Binding energy divided by the total number of nucleons present within the nucleus is called as "binding energy per nucleon". If we plot a graph between the mass number(f) and the binding energy per nucleon (in MeV) the graph is as shown in figure. The binding energy per nucleon is generally constant (about 8.5 MeV) for nearly all elements except very light ones

and for heavier elements its value is slightly less than average (8.5 MeV). This decrease in binding energy per necleon for large mass number is due to the coulomb repulsion between the protons which makes the nuclei less stable.

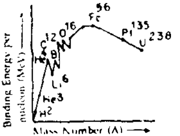


Fig.

Nuclear forces: The nuclear forces are strong attractive forces, which bind the nucleons (protons and neutrons) together in the nucleus of an atom. These forces are neither gravitational nor electrostatic in nature. Nuclear forces are of three types:

(i) The forces between two protons (pp force)

(ii) The force between two neutrons (nn force)

(iii) The force between a proton and a neutron (pn force)

All these forces are attractive and are of the same order.

Properties of nuclear forces

Short range: These forces are effective only within a very short range of the order of 10^{-15} m. They fall rapidly with distance. Coulomb's law is not applicable to these forces.

Strong interaction: These forces are different from gravitational or electric forces. We call it strong interaction force which perhaps the strongest force known in nature.

Charge independent: Nuclear forces between proton , proton-neutron and neutron-neutron is of the same order inspite of the fact that there is also repul-

sive force between protons and protons.

Transmutation: The conversion of one element into another by artificial means is called artificial transmutation of elements.

Fig below shows the method of artificial transmutation of nitrogen into oxygen. *G* is a glass chamber filled with nitrogen gas. *R* is a radioactive source of α-particles. The open end of the tube is covered by a thin silver disc *D*, *S* is the fluorescent screen and the scientillations on it can be observed by a high-power microscope *M*, when α-particles strike the nitrogen nuclei, scientillations are produced which are due to protons (*i.e.*, hydrogen nuclei). The nuclei reaction may be symbolically represented as

$$_2He^1 + _7N^{14} \rightarrow _8O^{17} + _1H^1$$

By artificial means a nitrogen nucleus is converted into a oxygen nucleus.

Nuclear charge = Atomic number × charge of a proton.

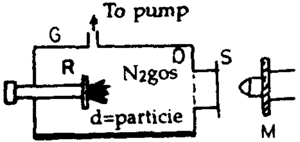


Fig.

$= 2 \times 1.6 \times 10^{-19}$ coulomb.

Nuclear Mass: It is equal to the sum of masses of protons and neutrons minus the mass defect.

Mass of nucleus $= Z M_p + (A - Z) Mn - \Delta m$

Z = Atomic number = number of protons.

A = Mass number = number of protons + number of neutrons.

Mp = Mass of a proton.

Mn = Mass of a neutron.

Δm= mass defect.

Nuclear reaction: The process of converting one element into another by artificial

means is called a nuclear reaction of transmutation.

Example: When an particle interacts with the nucleus of a nitrogen atom oxygen is produced. This reaction can be written as.

$$4\,He + {}^{M}N \longrightarrow 12\,O\,\frac{1}{2}\,H$$

Conservation of charge: In a nuclear reaction, the total charge of the reactant particles remains equal to the total charge of the product particles. As for example in the reaction.

$${}_{7}N^{14} + {}_{2}He^{4} \longrightarrow {}_{8}O^{17} + {}_{1}H^{1}$$

The total charge of the reactant particles is $(7 + 2) = 9$ and total charge of the product is $(8 + 1) = 9$ units. So the total charge is conserved.

Conservation of energy: In a nuclear reaction the total energy of the atoms before and after the reaction remains the same. The total energy of any particle is the sum of rest mass energy and kinetic energy.

Nuclear size: The nuclear radius is directly proportional to one third power of mass number (A)

Thus $R \alpha (A)^{1/3}$

or $R = R_0 A^{1/3}$

where $R_0 = 1.2 \times 10^{-15}$ m

The volume of nucleus is then given by

$$V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A$$

$$\therefore \quad V \alpha A$$

Thus volume of nucleus is directly proportional to mass number (A).

Discovery of neutrons: Chandwick found that when α-particles from a polonium source are bombarded on beryllium metals, a highly penetrating radiations are emitted which are not affected by an electric or magnetic field. By applying laws of conservation of energy and momentum to the emitted protons. He concluded that penetrating radiations consisted of uncharged particles having

mass nearly equal to the mass of a proton.

Properties of neutrons: The mass of neutron is about 1939 times the mass of an electron.

They have no charge and are present in the nuclei of all elements except that of hydrogen.

Inside the nucleus, neutrons are quite stable, but outside the nucleus they exist for a short time. A free neutron decays into a proton, an electron and an antineutrine. Symbolilically

$$_0N^1 \longrightarrow {}_1H^1 + {}_{-1}e^0 + \bar{v}^0$$

Since, neutrons have no charge, so they are not subjected to coulomb forces and hence they can easily penetrate even heavy nuclei. When $_{92}U^{235}$ is bombarded by a slow moving neutron it brings about nuclear fission releasing tremendous amount of energy.

Thermal neutrons: Slow moving or low-energy neutrons are those whose energy

is very much less than 1eV, actually near about $\frac{1}{40 eV}$ at room temperature. They are in thermal equilibrium with the matter through which they pass. That is why they are referred to as thermal neutrons. Devices for slowing down fast moving particles are called *moderators*.

Natural radioactivity: The nuclei of several elements of high atomic weight (such as uranium, radium, etc.) are unstable and undergoes spontaneous disintegration (breaking up) into more stable ones. This phenomenon is called natural radioctive decay or natural radioactivity. The radioactive decay occurs with the emission of either α-particles or β-particles or γ-particles. Natural radioactivity is a nuclear phenomenon and such disintegration change the nucleus of one element into that of another.

Artificial radioactivity: Naturally occurring radioactive element polonium emits α-particles. When these α-particles are

bombarded against Al or B, it was observed that the bombarded substances (i.e., Al or B) continued to emit radiations even after the source of α-particles had been removed. This means that radioactivity has been induced in Al. So the phenomenon according to which we start with a stable element and with the help of a nuclear reaction produce a radioactive element artificially is called artificia (or induced) radioactivity.

Radio-Isotopes: The artificial radioctive substances can be produced when particles like neutrons, deutrons, α-particles, protons etc, are bombarded against certain targets. *These artificially produced isotopes which exhibit radioactivity are called radioactive isotopes or simply radio isotopes.*

Example.

$_7N^{13} \longrightarrow {_6N^{13}} + {_1\beta^{0}} + V^{0}$. Here $_7N^{13}$ is a adio-isotope of ordinary nitrogen.

Use of isotopes: in medicine, agriculture, industry and for food preservation.

OUR UNIVERSE

Universe: Everything that exists is included in universe. It consists of the solar system, stars, planets, galaxies etc. There are billions of other galaxies like our solar system (also called milky way) in the sky. All such galaxies form the universe. The three main constitutents of universe are (i) solar system (ii) stars and (iii) galaxies.

Main constitutents of universe: 99% of the whole substances, contained in the universe, consists of two elements. These elements are hydrogen, and helium. All other elements present in the universe account for 1% of the matter only.

Solar system: It is the name given to the family of the sun. Earth is a part of the solar system. It consists of sun, nine

planets, asteroids, comets and meteors. Thus the bodies that revolve around the sun form the solar system.

Galaxy: A vast collection of stars is known as galaxy. These stars are held together by forces of attraction due to gravity. Galaxies exist in different ways. The two most common shapes are elliptical and spiral. Stars are not distributed uniformly in space.

Stars: Fiery luminous heavenly bodies are known as stars. Temperature of stars is very high and they continuously emit light. There are about 3.1×10^{21} stars in the universe. Sun is the nearest star, that we see. Stars are made up of vast clouds of hydrogen gas, and emit light continously due to fusion of hydrogen. It is a continuous process. Thus stars emit light continuously.

Naked eye stars: The stars that are visible to the naked eye are known as naked eye stars. There are about 5000 naked eye stars. Our eye can see about 2500 stars at a time.

Light year: It is the distance travelled by light in one year.

1 light year = 9.46×10^{12} km.

1 *Parsec* = *3.26 light years*.

Billions of stars are so far away, that it takes millions of years to reach their light to the earth. The distance of such stars is measured in light years.

Sun: Sun is a luminous mass of average size. The mass of sun is 740 times the entire mass of all the planets of the solar system. It is the main source of energy for the solar system. Sun light takes nearly eight minutes to reach the earth. The surface temperature of the sun is 5800 K. The temperature in the interior of the sun is about 20 billion K. The diameter of the sun is 1.4×10^{9} km. The distance of the sun from the earth is 1.5×10^{11} km.

Plants: The solid heavenly bodies that revolve around the sun are called planets. The solar system consists of nine planets These are Mercury, Venus, Jupiter. Earth. Mars, Saturn, Uranus,

Neptune and Pluto.

Planet	*Distance from sun in km*	*Radius in km x 10^3*	*Times for one revolution*	*Mass*	*No. of rounds*
Mercury	579×10^5	2.44	88 days	0.053	—
Venus	1082×10^5	6.05	225 days	0.8	—
Earth	1466×10^5	6.38	365.25 days	1	1
Mars	2279×10^5	3.39	687 days	0.1	2
Jupiter	7783×10^5	71.4	11.86 years	318	12
Saturn	14270×10^5	60.0	29.46 years	95	10
Uranus	28700×10^5	25.4	84 years	15	5
Neptune	45040×10^5	24.3	165 years	17	2
Pluto	59000×10^5	0.57	248 years	0.002	—

Constellations: On a moonless night, stars appear in the form of closed groups, and form recognizable shapes and patterns, known as constellations. The Indian name for constellation is Nakshatra. Some important constellations are ursa major, ursa minor, cosstopeia and orion.

Mercury: It is the smallest planet of the solar system. It is nearest to the sun. It revolves around the sun in 88 days. It also takes almost same time to complete one rotation about its own axis. From the earth, it appears as moving star towards the east in the morning (before sunrise) and towards the west in the evening (after sunset).

Venus (Shukra): It is the brightest planet as seen from the earth. In the universe it outshines everything except the sun and the moon. It is second in order of the distance from the sun. It completes one revolution around the sun in 225 days.

Earth: It is the third distant planet from the sun. Earth is the only planet of the solar

system having life on it. Life is possible on earth because it has plenty of water and atmosphere. It is neither too hot nor too cold. No other planet of the solar system has similar conditions. Thus life is not possible on them. The earth has atmosphere upto several hundred kilometers. Earth has one satellite called moon. But the earth has the following four independent motions.

1. motion in space along the sun as part of the solar system.
2. rotation of the earth around its own axis. It is also known as spinning of the earth. Rotation of the earth around its axis causes day and night.
3. the revolution of the earth around the sun, and
4. the precession of the axis of its rotation.

Kepler's laws of motion: proves that

1. The orbit of a planet, revolving around the sun is an ellipse with the sun as one of foci.

2. The planet moves around the sun in such a way, that the line joining the planet, tc the sun, sweeps equal areas in equal intervals of time.

Mars: It is slightly r.ddish in appearance. Due to this difference in colour it is easily distinguished from planets. It is said that mars may have life. However, it is still not clear as yet Mars has two small natural satellites.

Saturn: It is one of the most impressive satellites as viewed by a microscope because it possesses a set of well developed rings about it. These rings are composed of small particles and rocks measuring few kilometers in size.

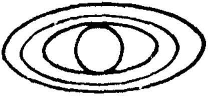


Fig. The Saturn (Shani)

Jupiter: It is the largest planet of the solar system. It takes more than twelve years to make a revolution around the sun. It has more than dozen satellites (moons).

Uranus: Willium Herschel discovered this planet in 1781. It is situated next to Saturn. It has four satellites. The most interesting feature of this planet is its rotation about its own axis. It revolves from east to west whereas all other planets rotate from west to east.

Pluto: It is the farthest planet of the solar system. It is a very cold planet and no life is possible on it.

Neptune: It was discovered in 1846 by French astronomer called U. J. Leverrier. No life is possible on it.

Super nova: These are super stars of the universe. The rate of production of energy of these starts is so high that they are on the verge of extinction.

Neutron star: These are stars of extremely high densities. The radius of these stars is of the order of 10 km.

Asteroids: Asteroids are very small planets of rock and metal, which revolve round the sun, mainly between Mars and Jupiter. The size of asteroids varies from few metres to 750 km in width.

Meteors: Many times streaks of light are seen in the sky during the night. These lights disappear within seconds. It is known as meteor or shooting star. Meteors are formed either by dust particles left behind by comet or by the collision of pieces of asteroids.

Meteorite: It is the fragment or high part, that may reach the earth's surface on being burnt. It does not burn completely on entering the earth's atmosphere and lands on earth. These can be said as stones entering the earth from the sky.

Comets: A comet is a collection of gas and dust which appears as a bright ball of light in the sky with a long flowing tail. The tail of a comet always points away from the sun. Comets revolve around the sun like planets. However, their period of revolu-

tion, around the sun is very large. Hailey's comet has a period of revolution of 76 years. It was last seen from the earth in 1986.

Protostar: After the formation of a star, the cloud of gases began to contract. The contraction of gases occurs due to force of gravity between the molecules. This contracting mass is known as a protostar.

Big Bang: All the bodies of the universe are not stationary but receding from each other. Thus the universe is expanding continuously. Some time in the past, some event must has happened when universe started expanding. It is known as big bang.

Artificial satellites: The super crafts sent by men to encircle the earth is known as artificial satellite. These are called as satellites, because they evolve around the earth in the same way as the planets revolve around the sun. The first Indian artificial satellite is named as 'Aryabhatt'.

Difference between a star and a planet:

Star	Planet
A star has its own light and emits it continuously.	A planet has no light of its own. It shines on receiving light from the star.
Stars twinkle at night.	Planets do not twinkle at all.
Stars are very big in size.	Planets are very small in size.
Star is a big mass of extremely hot gas.	Planets are solid bodies made of rocks and minerals.
Stars do not change their relative positions in the sky.	Planets are changing their relative positions continuously.

Energy Generation in the sun: How sun is emitting energy continuously? Answer to this question was given by physicist I. Hans Bethe in 1939. He said that the interior matter of the sun is converted into

energy, in accordance with the Einstein's energy equation, $E = mc^2$,

where E = energy released

m = mass defect

and c = velocity of light

It is assumed that the sun is losing 4×10^9 kg of mass per second and whole of this mass is converted into energy. It radiates energy at a rate of 10^{26} J per second and is the main source of energy for all the planets of the solar system. The earth receives only a part of his energy. One third of the energy is reflected back by the earth's surface. Similarly other members also reflect energy into the atmosphere. This reflection of light from the earth's surface make us to see objects. Sun is the head of the solar family and main source of energy to the earth. Life on earth is possible only due to sun. The surface temperature of the sun is 5800 K. No material can remain in solid or liquid state at this temperature. As

such, sun can be said as a huge ball of gases. The temperature at the centre of the sun is estimated to be about 20 billion K. *i.e.* 20×10^9 K.

Important Data of the Sun

Data	Measurements/ values
Mass	1.99×10^{30} kg
Diameter	1.39×10^9 m
Mean density	1.4 times the density of water
Distance from the earth	1.5×10^{11} m
Surface area	1200 times the surface area of the earth.
Volume	1300000 times the volume of the earth
Central temperature	20×10^9 K
Surface temperature	5800 K

Solar constant	135.8 W/m^2
Pressure at the centre	2×10^{12} N/m^2

Venuses: Just like the moon, the Venus also shows phases *i.e.* increase and decrease in size. The phases of the moon can be seen with the naked eye.

The phases of Venus can be observed with the help of a low power telescope and a good pair of binoculars. The phenomenon of occurrence of phase in planets is described below. Planets are visible to us on account of reflection of sunlight from their surfaces. The various positions of the Venus while moving in its orbit around the sun are shown in Fig. (a). The part of the planet, on which sunlight falls is shown clear. The part away from the planet, that does not receive any light is shown shaded in the figure. From the earth, we see only the lighted part of the planet.

Due to this reason, we obtain different

phases in Venus. The full Venus is farthest from the earth and smallest in size.

Formation of Day and Night: We know that earth is rotating continuously about its axis. This rotation of the earth about

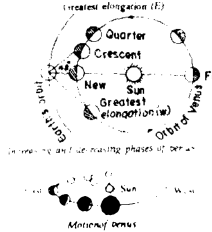


Fig. Motion of Venus

its axis causes day and night. The part of the earth facing the sun, receives sunlight. This period, during which sun is visible from the earth is called day. The part of the earth that does not receive sunlight is called the night. The continuous rotation of the earth around its axis, causes day and night.

Focault's Experiment: French Scientist J. B. L. Focault gave an active demonstration of rotation of the earth about its axis with the help of a freely swinging pendulum. This experiment is known as Facault's experiment. As shown in Fig. it consists of an iron ball with the lower conical part. The ball was suspended by an inextensively wire about 66 m long from the centre of a dome in Paris. A line was marked in the North-South direction on the sand dome. The pendulum was set to oscillate in the North-South direction. During each oscillation, the pointed end of the ball will cut off furrow in the sand below it. It was observed that each

furrow was in a slightly different direction than the previous one. To the audience, it looked that the dome is turning slowly about its axis. It shows that the earth is rotating. When the plane of direction of motion of pendulum remains the same, the meridian of the dome goes on changing. It proves that earth is rotating continuously about its axis.

Revolution of earth around the sun: The earth revolves around the sun in a fixed orbit called the **ellipse**.

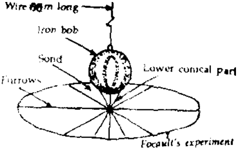


Fig.

Solar Day: A solar day is the time between two consecutive noons on successive days.

Sidereal Day: It is the time interval between two consecutive instants when a fixed star (far away from the sun and the earth) comes just opposite to the observer on the earth on successive days.

Difference between sidereal and solar days.

Sidereal day	*Solar day*
(i) It is defined with reference to a fixed star *i.e.* it is the time during which the earth rotates through 360°. (ii) One sidereal day = 23 hrs. 5·6 minutes 4·1 sec.	It is the time interval between two consecutive noons. We know that the earth is revolving around the sun in fixed orbits. If θ is the angle covered by the earth around the sun, thus the solar day = $360° + \theta$ one solar say = 24 hrs.

Air Pollution

Air pollution is increasing day by day. It is said that motor-vehicles are responsible for this. It is a fact because the motor vehicles emit large amounts of gaseous pollutants into the air and hence cause increased air pollution. The various pollutants emitted by the exhausts of motor vehicles like trucks, cars, scooters and buses are:

(i) Carbon monoxide, CO (ii) Carbon dioxide, CO_2 (iii) Sulphur dioxide, SO_2 (iv) Unburnt hydrocarbons like octane, C_8H_{18} (v) Nitrogen oxides like NO and NO_2. The pollution produced by vehicles or automobiles can be checked to some extent by the following methods:

1. By the catalytic oxidation of exhaust

gases using platinum catalyst.

2. By adding tetraethyl lead to petrol.
3. By keeping the vehicle properly tuned for optimum ignition of fuel.

Industrial plants are also responsible for air pollution. For example if an industrial plant or factory is set-up near a city for the extraction of copper metal from its sulphide ore, then it will emit gaseous pollutants like: carbon monoxide, CO; carbon dioxide, CO_2 hydrogen sulphide H_2S; sulphur dioxide, SO_2; and sulphur trixide, SO_3. All these noxious gases will pollute the air in and around the city. fuels like coal and oil in the factory, whereas H_2S, SO_2 and SO_3 come from the processing of sulphide ore will pollute the air.

The harmful effects of these gases are dangerous. Carbon monoxide is a poisonous gas which leads to respiratory problems in men and animals; carbon dioxide enhances the green-house effect leading to excessive heating of the earth and its atmosphere; hydrogen sulphide is a

poisonous gas which tarnishes silver objects and blackens lead paints; sulphur dioxide and sulphur trioxide produce acid rain and damage crop plants and marble of buildings and it may cause asthama to human brings.

Further some of the important effects on the local climate caused by the installation of heavy industries are— (i) Air pollution (ii) Rise in atmospheric temperature (iii) Change in humidity, (iv) Ecological imbalance.

Corrosion

Corrosion of metals is the slow destruction of metal as a result of chemical attack by air, moisture and pollutants present in the atmosphere.

In the process of corrosion, the useful metals are oxidised by the oxygen presents in the air in the presence of moisture to form metal oxide and metal hydroxide.

These metal compounds are non-sticky and strif off exposing fresh metal surface for further corrosion.

Thus, corrosion is an unending process which gradually finishes up the whole metal.

Iron metal corrodes in the presence of air and moisture to form a brown coating of a mixture of iron (III) oxide and iron (III) hydroxide on its surface.

Actually, corrosion of iron is called rusting. While other metals corrode, iron rusts.

The two conditions necessary for the corrosion of metals to takes place are: (i) presence of oxygen, and (ii) presence of moisture in air.

The presence of pollutants in the air increases the rate of corrosion of metals. This is because air polluted with smoke emitted by factories contains acidic gases like nitrogen dioxide, sulphur dioxide and carbon dioxide, which corrode the metals even more faster.

Corrosion of metals can be prevented by coating the metal with a protective layer of paint, varnish or grease. A metal like iron can, however, be protected from corrosion by giving a thin coating of another metal like tin zinc or chromium, which cannot be cor-

roside easily. Some metals build up their own protective layer. For example, when zinc metal is exposed to atmosphere, it reacts with the oxygen of air to form a thin film of zinc oxide on its surface. This oxide layer is impervious to air and moisture and protects zinc metal from further corrosion. Similarly, aluminium metal also builds up its own protective oxide layer which protects it from further corrosion.

Polluted air also corrodes metals because it contains acidic gages like sulphur dioxide and nitrogen dioxide. In the atmosphere, sulphur dioxide is converted into sulphuric acid whereas nitrogen dioxide is converted into nitric acid.

Sulphuric acid and nitric acid are washed down to earth with rain water causing acid rain. The dilute acids present in rain corrode metal gradually.

Any sculpture made of bronze metal lost its lustre due to corrosion of copper metal present in it which is caused by acidic oxides present in polluted air.

Smog

Smog is a major pollution problem is big metropolitan cities having a lot of industries and automobiles. Smog is a combination of smoke and dust particles with the tiny droplets of fog containing poisonous gases discharged by the burning of fuels in homes, factories and automobiles.

Smoke and Dust + Fog and Harmful gases — smog.

The harmful gases present in smog are usually sulphur dioxide and peroxy acyl nitrate (PAN). Smog forms a sort to thick, low lying cloud over the highly populated metropolitan cities during the winter season. Smog occurs in winter when the suspended tiny droplets of fog containing poisonous pollutants condense on the solid particles of smoke and dust in the air. The smog produced from sulphur dioxide as pollutant is called chemical smog whereas that produced by the action of nitrogen oxides is called photochemical smog.

Smog is a very dangerous air pollutant

and it have the following effects—

1. Smog causes irritation to the eye, nose and throat.
2. Smog causes respiratory complications like asthma attacks. In fact, smog is a very serious health hazard. Smog is harmful to all the organisms which breathe it.
3. Smog has an adverse effect on the growth and development of plants.
4. Smog reduces the visibility to a very low level causing the disruption of road and air traffic and accidents.

Particulate

Most of the particulate pollutants are the products of combustion of fuels (burning of fuels) in homes, transport and industry.

For example, burning of coal produces smoke and flyash, which is discharged into the atmosphere. Smoke and flyash contain unburnt carbon particles.

Incomplete combustion of hydrocarbon fuels like kerosene produces particulate pollutants like soot. Combustion of petrol in

automobiles emits various particulate lead compounds into the air. The cement industry emits particulates called cement dust into the atmosphere. The industrial operations like blasting, drilling, grinding, crushing mixing and drying, also release particulate matter into the atmosphere, and cause pollution. Some of the natural sources of particulate matter in the atmosphere are—

Dust storms, Sand storms, Forest fires, Plants, Volcanoes and Sprays from ocean waves.

Dust storms and sand storms put a lot of dust particles and sand particles into the atmosphere; forest fires give a lot of smoke to the air; plants give particulates like spores, pollen grains, bacteria and fungi into the air; volcanoes emit smoke and mineral particles into the atmosphere whereas spray from the ocean waves puts common salt particles into the air.

The finely divided solid or liquid particles suspended in air are called particulates.

The particulates are a kind of pollutants

in the air. Some of the examples of particulate matter of particulates in the atmosphere which act as air pollutants are: Smoke, Fumes, Mist, Spray, Fly-ash, Spores, Pollen-grains, Fungi, Bacteria, Viruses, Hair, Lead dust, Fur, Mercury dust, Asbestos dust, Cement dust, Sand, Sodium chloride, Dust Fluorides and agricultural chemicals like Pesticides and Insecticides.

The various ill effects of the particles matter of the atmosphere are as follows—

Particulates reduce the visibility by producing haze in the atmosphere.

The Particulate pollutants cause various allergic reactions, bronchial asthma, tuberculosis and other infections. This is because particulates attack the respiratory track of men and animals and damage the tissues in the lungs.

The particulates like smoke blacken the buildings and our clothes.

Particulates in the air reduce the amount of solar radiation reaching the earth and

hence disturb the thermal balance of earth.

The aerosol particulates like fog are capable of absorbing and concentrating poisonous gases and hence cause more serious air pollution like smog.

All the metals are toxic to some extent to all the living organisms like men, animals and plants. Some metals are less toxic whereas others are more toxic. some of the more toxic metals when inhaled or ingested in appreciable amounts are : Lead, Mercury, Cadmium, Zinc, Arsenic Iron, Tin and Aluminium. Many metals are toxic to the plants even in small quantities and render them unsafe for human consumption.

The lead particles and mercury particles are the two types of metallic particles which are very toxic to living organisms.

Asbestos particles are the non-metallic particles which are very toxic to living organisms like human beings.

Lead is a very poisonous metal. The concentration of lead particles in the air of

big cities in quite high. Lead particles are emitted into the air through automobile exhausts (because of the presence of tetraethyl lead in petrol). The industries engaged in lead *mining*; lead *smelting* and refining; manufacture of lead storage batteries; lead alloys; and lead paints, etc., also *contaminate air*, *water*, *soil* and food crops with lead particles. The use of lead aresenate as a pesticide also causes lead pollution. The ill effects of lead particles on the human beings are the following: The excessive level of lead in the tissues and blood of human beings causes a disease known as lead - poisoning. The initial symptoms of lead poisoning are Nausea, Insomnia, Constipation, Fatigue, Abdominal pain and Anaemia. These are followed by muscular paralysis and mental disorders. Lead poisoning can even lead to permanent brain damage in children.

The mercury metal and its compounds are highly toxic (highly poisonous). Mercury metal enters the environment mainly through

the dumping of mercury-containing industrial wastes into the environment, particularly water bodies.

Mercury poisoning causes a disease known as minamata in human beings. The mercury poisoning or minamata weakens the muscles and vision and hearing capacity are impaired. This is followed by brain damage leading to metal retardation and paralysis. The crippled person quite often becomes insane and then dies Minamata disease resulted in the death of fishermen in the coastal areas of Japan who are fish contaminated with mercury.

Fish from polluted water is the major source of mercury intake by man. Mining operations for mercury ores and the use of mercury compounds as fungicides and pesticides in agriculture also releases substantial amounts of mercury particles into the environment. Combustion of fossil fuels like coal and petroleum, and roasting of sulphide ore of mercury release mercury vapours into the atmosphere.

Asbestos

Asbestos is a fibrotic lung disease which is caused by the prolonged inhalation of asbestos particles. The asbestos dust particles keep on depositing in the lungs and cause a progressive decrease in the functional capacity of lungs. The normally thin-walled alveoli and small bronchioles become thickened with fibrous asbestos tissue and the lungs lose their elasticity.

The important sources of asbestos dust are asbestos mining, processing and manufacture of asbestos sheets, flooring (tiles), insulating materials, fire-proof fabrics safety curtains and automobile brake linings. Asbestos is a mineral fibre or fibrous material. Asbestos dust is a hazardous air pollutant. The prolonged inhaling of asbestos dust by human being causes a disease known as asbestosis, and also lung cancer.

Noise pollution

The unwanted, harsh and loud sound is known as noise. The disturbance produced

in environment by the undesirable loud sounds of various kinds is called nouse pollution. Noise has an adverse effect on the mind, and behaviour of a man. Noise is considered a pollutant. It is the loudness and duration of the noise which disturbs us and causes physical discomfort and temporary or permanent damage to our hearing capacity. Noise pollution has become especially acute in (city areas) because of different kinds of loud sounds produced by various machines which vary from loudly played transistor radio and loudspeaker to the thundering of a jet plane.

The important sources of noise pollution in transport homes, and industry are as follows.

Road, rail and air traffic cause a lot of noise pollution in all the big cities. The engines and horns of vehicles like motor-cycles scooters, cars, trucks, buses trains and even aeroplanes in a big city produce a lot of noise. The local and inter-state trains produce noise pollution by blowing their

powerful horns. The landings, take offs and flying of aeroplanes is another source of loud noise in big cities.

The sources of noise pollution in the homes are loudly played music systems like radios, stereos, television and loud-speakers some people are in the bad habit of switching on their music systems at full volume. This creates a lot of noise and pollutes the environment. Similarly, some people use loud-speakers at full volume during social and religious functions or during elections. This creates unbearable noise pollution in the whole locality. The modern household gadgets like mixer and grinder, vacuum cleaner, washing machines, coolers, air-conditioners, etc., are other sources of noise pollution in homes because all these appliances make quite loud noises when they are in use.

Almost all the factories and industries use various types of small and big machines which make loud and irritating noises of different kinds. Printing presses, electricity

generating plants, textile factories, steel fabricating plants, etc., all of produce a lot of noise pullution inside the factory as well as in their neighbourhood.

Sudden noise from a blast or an explosion can cause acute damage to the ear drum whereas prolonged exposure to loud noise can cause gradual hearing loss and ultimately lead to deafness.

Noise interferes in communication to other persons. During the rattling noise of various machines in a factory cannot talk or hear properly even a person standing near-by.

Noise causes headache, and extreme emotional behaviour. It also aggravates existing diseases.

Noise increases nervous tension, blood pressure and heart trouble. Such effects have been noticed particularly among factory workers who are exposed to constant noise from machines.

Noise disturbs our peace of mind, it disturbs our sleep as well as our work.

Space Exploration

Space means outer space or the region beyond earth. It is that portion of the universe which is beyond the immediate influence of earth. The study of region beyond earth and the objects present in it is called space science.

Space science is used for continuous weather monitoring and weather forecasting on the earth. This is done by using weather satellites stationed in outer space.

Space science is used for making long distance communications, like long distance telephone calls, television broadcasts and radio broadcasts. This is done by means of communication satellite stationed in outer space and is known as satellite communications.

Space science is also used for the collection of information about other planets and outer space. This is done by sending the space probes.

A communication satellite is a spacecraft circling high above the earth which can receive radio-telephone, radio and T.V. signals from a particular earth station, amplify these communication signals and then retransmit these amplified signals to various other earth stations around the world. Communication satellites are being used increasingly to handle long distance telephone, television and other transmissions around the world. Our country has developed its own communication satellite INSAT-1 series which have brought television service even to remote, inaccessible villages of our country.

Satellite communication

Satellite communication is an important application of space science. "Satellite communication" means "communication through the use of satellites."

In satellite communications, the artificial earth satellites positioned in space above the earth are used as relay stations for amplifying and transmitting the signals of radio telephones, radio and television broadcasts from one part of the earth to other parts.

In fact, earth satellites provide radio and television service to much of the world. Communication satellites have also been used to relay educational and health information to isolated villages directly through satellite television.

An important advantage is that communication satellites can be used when other forms of communications are either impossible or too expensive. Another advantage of satellite communication is that the hour-to-hour changes in the atmosphere have no adverse effect on the quality of programmes broadcast viasatellite. The signals received back from the satellite are absolutely free from any distortion.

A communication satellite is a spacecraft circling high above the earth. A com-

munication satellite has an amplifier and a transmitter which work with solar energy. A net-work of transmitting and receiving ground-stations is set up throughout the country or throughout the world. The extremely short wavelength. T.V. waves, radio waves and radio-telephones waves carrying the message are beamed up to the satellite from one of the ground stations. The satellite amplifies these electromagnetic communication signals and then transmits the amplified signals to all the far ground stations. These ground stations have receivers which re-convert the signals obtained from satellites into radio programmes, telephone conversation or T.V. programmes. Hence a communication satellite in the sky acts as a relay station, amplifying and re-transmitting radio. T.V and radio-telephones signals.

Moon is the natural satellite of the earth but it cannot be used for communication purposes due to the distance between earth and moon is very, very large.

The time of rotation of moon on its axis

is not 24 hours like that of earth.

Moon is not rotating in the equatorial plane of the earth.

Weather monitoring

These days weather monitoring and forecasting is being done with the help of those artificial satellites called weather satellites stationed in outer space. The weather satellites contain a wide variety of scientific instruments to monitor the climatic factors like air pressure, humidity, air temperature, and other changes taking place in the upper layer atmosphere of earth. Weather satellites are fitted with powerful television cameras to take the pictures of cloud formations in the atmosphere over large areas of the earth's surface.

Weather satellites also carry a large variety of scientific instruments of sense the weather condition prevailing in the atmosphere. The photographs taken by satellite cameras and other related data are relayed to the earth. In this way, the weather satellite cameras provide large scale matter and

weather photographs of the different parts of earth. From these satellite photographs and other related data relayed by weather satellite, it is possible to know in advance whether a particular area is going to have rainfall, snowfall or even a cyclone can be forecasted.

India has so far launched three artificial satellites which work both as communication satellites as well as weather satellites.

These are INSAT-1A, INSAT-1B and INSAT-1C. (INSAT stands for Indian National Satellite)

Out of these three artificial satellites INSAT-1A got damaged completely during the launch process whereas the power system of INSAT-1C got damaged partially. But INSAT-1B is in perfectly working order since October 1983 when it was launched. Even INSAT-1C is working but at a reduced capacity.

At present in our country, artificial satellite INSAT-1B is being used for weather forecasting, especially rainfall, snow-fall and

cyclone forecasting since 1983.

INSAT-1B is sending weather photographs showing the cloud formations over large areas of our country every half-hourly. These satellite photographs are studies by the experts of Meteorological department and then weather forecasting is done on the basis of these atmospheric pictures and other related data.

INSAT is being used for direct broadcasting of television programmers to the remote areas of our country and is being used for long-distance telephone calls like overseas communications.

INSAT is being used for continuous weather monitoring and weather forecasting by making meteorological observations in the sky and sending atmospheric pictures to the earth and is being used for connecting all the radio stations and television stations of the country to a National Hook-Up. The National-Network. T.V. programmes, Radio programmes and weather forecasting in India is being made possible by INSAT-1B.

Information from other planets

The collection of information about other planets and outer space is done by sending specially designed space vehicles called space probes. The space probes contain a wide variety of scientific instruments and television cameras, etc., to collect and transmit data and pictures of other planets and outer space. These space probes have provided us close-up pictures and other data about planets and other objects in the other space, and have vastly increased our knowledge about space and the objects in it. Sometimes manned space vehicles are also sent into outer space to collect data and make other studies. America and Soviet Union are now working towards establishing permanently manned space stations in outer space to collect information about other planets and outer space. Russians launched their space-station programme in 1971 with the Salyut series of space-station. Equipped for earth, solar and astronomical observations and material processing experiments,

they are visited regularly by crews flown up in Soyuz space-craft. Some crew members have stayed on salyut space-station for over 6 months at a time.

The exploration of outer space began with the successful launching of the Russian artificial satellite called Sputnik-1 in the year 1957, and accelerated by Yuri gagarin's first manned flight in space aboard a space-craft called Vostok-1 in the year 1961. In the same year, Alan shepard piloted the first American manned spacecraft and President John Kennedy of America set the goal of landing a man on the moon and returning him safely within the same decade. The first space-walk was undertaken by Alexei Leonove is October 1964.

The most exciting space programme involving the moon has been the Apollo project of America which ultimately landed man on the moon. It was the Apollo-11 space-craft of America which took man to the moon. The two astronauts who landed on the moon on July 20, 1969 were Armstrong and Aldrin.

They brought back samples of moon soil and rocks for analysis and examination. In 1973, Russia sent an unmanned wheeled vehicle Lunakhod aboard Luna space-craft to moon which also brought back samples of moon-soil to the earth for testing. Lunakhod was driven by remote control from the earth.

The moon has been explored by a variety of moon probes called 'Luna' series begun by Russia in the year 1959. Some space crafts crashed into the moon's surface others flew past the moon or went into moon's orbit Luna-3 was the first space-craft to go completely round the Moon. In the year 1960, Luna-3 photographed that side of the moon which is not visible from the earth and transmitted the first photographs of this area. These photographs show the presence of craters, dark plane and mountains on the other side of the moon, just like those present on its visible side and observed through telescopes.

Exploration of the planets has been carried out by unmanned probes. Though the

planets are millions of kilometres away, but space probes have already reached some of the planets and are approaching other planet. The American Mariner space programme has studied three planets: Mercury, Venus and Mars through space probes.

SYMBOLS FOR PHYSICAL QUANTITIES

Name of quantity	*Symbol*
absorportion factor	a
acceleration	a
activity, radioactivity	A
admittance	Y
angle of optical rotation	a
angular frequency	ω
angular velocity	ω
area	A, S
atomic mass	m_a
Bohar magneton	μB
Bragg angle	θ
bulk modulus	K
characteristic temperature	θ
charge density	ρ
coefficient of friction	μ
compressibility	k, K
conductivity	k
cross section	σ

cubic expansion coefficient	γ
Curie temperature	θ_c Tc
Debye temperature	θ_D
decay constant	λ
density	ρ
diffusion coefficient	D
Dirac constant	h
efficiency	n
electric current	I
electric current density	j
electric dipole moment	p pe, u
electric flux	ψ
electrical potential	V
electric potential difference	U, ΔU
electric susceptibility	x_e
electron mass	m, m_e
emissivity	ε
enthalpy	H
entropy	S
equilibrium constant	K
fermi energy	E_F ε_F

frequency	v, f
gibbs function	G
half life	$T\frac{1}{2}$ $t\frac{1}{2}$
Hall coefficient	R_H
heat capacity: at constant pressure	G_p
heat capacity: at constant volume	Ω
heat flow rate	ψ
Helmholtz function	A, F
illuminance, illumination	Ev, E
impedance	Z
internal energy	U, E
irradiance	E_e, E
Joule-Thomsen coefficient	μ, μJT
kinematic viscosity	v
kinetic energy	T, K_k, K
linear attenuation (extinction) coefficient	μ
linear expansion coefficient	a
linear strain (relative elongation)	θ

loss angle	δ
luminance	L_v, L
luminous emittance	M_v, M
luminous flux	φ $v\varphi$
luminous intensity	I_v, I
magnetic field strength	H
magnetic flux	ψ
magnetic flux density, magnetic induction	B
magnetic moment	m
magnetic moment of particle	m, μ
magnetic quantum number	M, m_1
magnetic susceptibility	x, x_m
magnetization	M
magnetomotive force	F_m
mass excess	Δ
mass number, nucleon number	A
mean free path	λ, l
mean life	τ
molarity	mA
molecular momentum	p (p_x, p_y, p_z)

molecular position	$r\,(r_z, r_y, r_z)$
molecular velocity	$u\,(u_x, u_v, u_z)$
momentum of inertia	I
momentum	P
most probable speed	u
mutual inductance	M, L_{12}
Neel temperature	θ_N, T_n
neutron mass	m_n
nuclear magneton	μ_N
nuclear spin quantum number	I, J
nucleon number, mass number	A
Number of molecules	N
orbital angular momentum	L, l_l
osomctic pressure	II
packing fraction	f
permeability	μ
permittivity	ε
Planck function	Y
plane angle	$\alpha\ \beta\ \gamma\ \theta\ \varphi$
polarizability	$\alpha\ \gamma$
position vector, radius vector	r

potential energy	E_v, V, φ
principal quantum number	n, n_i
propagation coefficient	γ
proton mass	m_v
quantity of heat	q, Q
quantum number of electronic spin	S, s
quantum number of nuclear spin	I
quantum number of vibractional mode	v
radiance	Le, L
radiant existence	M_e, M
radiant flux, radiant power	φ_e, φ
radiant intensity	I_e, I
ratio of heat capacities C_p/C_v	γ k
reduced mass	μ
reflection factor	ρ
refractive index	n
relative atomic mass	Ar
relative density	d
relative permeability	μr
relative permittivity	ε_r

(dielectric constant)	
relaxation time	τ
resistivity	ρ
Reynolds number	(Re)
rotational quantum number	J, K
shear modulus	G
solid angle	ω, Ω
specific heat capacity: at constant pressure	C_p
specific heat capacity: at constant volume	C_v
specific optical rotatory power	αm
specific (ratio) activity	a
specific volume	v
speed	u
spin quantum number	S, s
surface charge density	σ
surface tension	γ, σ
susceptance	B
temperature	T, t
thermal conductivity	λ

thermal diffusion coefficient	DT
thermal diffusion factor	σT
thermal diffusion ratio	KT
thermal diffusivity	α
thermodynamic temperature	T
time	t
transmission factor	τ
velocity distribution function	$f(c)$
velocity of light in a vacuum	c, c_o
velocity of sound	c
vibrational quantum number	v
viscosity	n
volume	V, v
volume (bulk) strain	
wavelength	λ
wavenumber	σ
weight	γ
work	[illegible]
work function	
Young's (modulus of elasticity)	

OUR MINI SERIES

Dictionaries

ENGLISH—ENGLISH
ENGLISH—HINDI
HINDI—ENGLISH
ENGLISH—MARATHI
COMPUTER DICTIONARY
SCIENCE DICTIONARY

Formulaes

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